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EDITORIAL

Engineering Philosophy

IN OUR postwar world of confusion, conflicting interests, and uncertainty in many fields we find in some public expressions, a note of despair, a threat of doom. It seems that all the wealth, power, widely distributed prosperity, scientific and engineering progress, private enterprise, freedom and representative government of the United States have not brought and end to human problems, or even lessened them materially. Some people are disillusioned. Some strong minds lose their perspective.

In substance, their indictment of progress is that it has failed to remove all or most of the obstacles in the path to the pot of gold at the end of their rainbow. They recognize that some old problems have been solved, and some specific obstacles removed, but condemn what we have called progress for failure to prevent the intrusion of new problems and obstacles. For old problems that we had learned to live with, it has substituted strange and terrifying new ones with which we know not how to deal.

From the bare fist we have progressed in weapons to the H-bomb. From the two-man grudge fight we have progressed to the world war. From crooked-stick subsistence farming we have progressed to the farm product surplus. From the tribal taboo we have advanced to the drawing of a fuzzy line between liberty and license. From child labor problems we have moved on to problems of juvenile delinquency. From the rude cave, skin or log hut we have progressed to a housing shortage. In scandal mongering we have advanced from the whisper to the screaming tabloid. From the stunning, stupefying problems of the 12 to 20-hour work day we have advanced to the challenging problems of leisure.

But is the trouble with progress and all of its new problems, or is it with our outlook on life?

Is this indictment by human beings based on a true appreciation of their own nature?

Is the pot of gold worth more than the sense of accomplishment at overcoming some of the obstacles?

Is the ultimate in living either a genteel, problemless idleness or riotous dissipation at no human cost?

Is the end, purpose, and justification of our life on earth a prolonged supine existence?

Should a man be shielded from problems until he is 50 because he is too young to face them, and thereafter because he is too old?

Where is the pioneering spirit which led our forefathers to meet new problems more than half way?

It occurs to us that the time has come for engineers, scientists, business leaders, educators and others in whom the pioneer spirit may still live, to clarify the nature and objectives of progress.

It is time to dispel the sedative illusion that the purpose and direction of progress in engineering or any other human activity is toward a world devoid of problems. The end of the rainbow is a navigating horizon, not a destination.

It is time to remind people that problems originate in their very nature, their instincts, their minds, their impulses to do, and to have, and to live. The solution of one problem starts others developing in the manner of a chain reaction.

It is time for engineers to remind people that progress can be measured more accurately in terms of the finite numbers and proportions of problems already solved, than in terms of the infinite number and complexity of the obstacles apparently blocking our further progress. Our stockpile of recognized but unsolved problems is an indication of alertness rather than failure.

It is time to remind people that engineering mastery of many major physical problems causes unsolved problems in human relations to stand out in more prominent relief.

It is time remind people that the tragedies of life are not the problems they face, but the ways in which they face or fail to face their problems. There is tragedy in the untold numbers who have never had opportunity to solve more than the basic problems of a miserable day-by-day existence; the few who with great endowments of intelligence, training, and worldly goods, have failed miserably to apply them toward the solution of any important problems; and the great majority who fail to fully develop and live up to their inherent capacities and opportunities to hurdle obstacles to effective living.

It occurs to us that the highest purpose of engineering is not to reduce the total problems obstructing the progress of mankind, but to increase the number which have been solved; to improve the means, mechanics, and efficiency of living, so that more men may enjoy the opportunity, training, stamina, and zest for effectively tackling problems somewhat beyond those of animal existence. It means more efficiency, better use of resources, more purposeful application of the laws of nature.

From this viewpoint engineers and others might find problems stimulating rather than depressing. It seems worth considering as a philosophy of engineering, and as an outlook to be advanced in order that engineers and their developments may be better understood by the public.

More Than a Pseudo-Scientific Racket

RECENTLY that venerable oracle of the farm equipment trade, "Farm Implement News", raised a question which, coming from it, could only have been hypothetical and calculated to inspire an authority to clarify a point for some of its readers.

Waiting till it caught Floyd W. Duffee, (head, agricultural engineering department, University of Wisconsin) with both hands in his pockets so he couldn't swing before counting ten, FIN said "Floyd . . . we have long feared that ag engineering was a pseudo-scientific racket . . . ."

Then it braced its editorial legs and caught the full force of his reply on page 53 of its February 10th issue.

Cool as a Wisconsin winter, Duffee reviewed some facts. Agricultural engineering training is engineering training *plus*. The engineering training is in the mathematics, materials, machine design, thermodynamics, fluid dynamics, factory production methods, machine testing and other subjects common to other branches of engineering. The "plus" includes training in the job to be done by engineers in agriculture, in terms of principles of soil tilth and fertility, crop culture, and animal production. It may also include some training in economics, public speaking, and various other subjects, including the journalistic approach to a better world and to progress in the farm equipment business. At Wisconsin, and presumably elsewhere, agricultural engineering teachers have even exposed their students to the philosophies of some of the recognized leaders in the farm equipment business and other phases of human progress.

The agricultural engineering curriculum has provided a worthy challenge to war veterans pursuing education with a somewhat mature view of their objectives. It has satisfied the "money's worth" requirements of a lot of boys who have worked much or all of their way through college. It has helped man the engineering departments of the farm equipment industry and provided some especially competent men for the sales and service ends of the business. It has manned the engineering research activities of the U. S. Department of Agriculture, and of numerous state and local public service activities in the interest of agriculture. It has trained men to teach farm mechanics to county agents, farmers, students of vocational agriculture, and sales and service personnel of the farm equipment industry.

Duffee might have added that for years FIN has sat respectfully at the feet of Dr. J. B. Davidson and other teachers of agricultural engineering, using a far greater poundage of pulp for notes than for paper *(Continued on page 148)*

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A Pneumatic Gun for Elevating Baled Hay

By J. B. Liljedahl and E. L. Barger

THE purpose of the investigation on which this paper is based was to compare a pneumatic gun with other methods of elevating and conveying bales of hay. The pneumatic gun, which is described, was designed and is owned by F. W. Moffett, Jr., owner of Idylbrook Farms near Rochester, N. Y. At present it is not being built or sold commercially. Mr. Moffett used this gun in 1948 to elevate approximately 15,000 bales of hay on his own dairy farm. It was used the last half of the 1949 haying season at Iowa State College.

Operation. To operate the gun it is placed 10 to 15 ft away from the barn door opening into which the bales are to be shot. After a few minutes experience with the gun, the operator can aim it accurately enough to shoot bales through a barn door opening. The gun normally rests on the ground to facilitate loading and to provide a solid foundation to withstand the recoil.

The truck or trailer hauling the bales is driven beside the gun so that the operator can readily place the bales in the gun. To fire the gun, the operator opens an air valve by means of a rope suspended from a pole beside the truck. This is shown in Figs. 1 and 2. The bales are usually shot into the haymow door or into side doors. If a large window can be opened into the haymow, bales can be shot through it. This is not a recommended practice because some the bales will miss the smaller opening.

The height and distance to which the bale will go is a function of the pressure on the piston, the vertical angle of the gun, and the weight of the bale. The pressure and the vertical and horizontal angles can be changed in order to place the bale anywhere within the range of the gun.

In shooting the bales into the barn a few leaves are lost. There will be some leaf loss from baled hay regardless of the way it is handled. No attempt was made during this investigation to evaluate these losses although they were observed to be not excessive.

Design. The main part of the gun is composed of a cylinder and piston surrounded by an air supply tank. Fig. 3 is a schematic diagram of the gun. When it is in operation, air comes from the compressor through a pressure regulator, and then to the air supply tank surrounding the cylinder. The pressure regulator can of course be adjusted. Air enters the bottom of the cylinder by way of a quick-opening valve which is actuated by the rope hanging from a pipe above the gun. The piston is stopped at the top of the stroke by the air, which is compressed above the piston and in the buffer air tank. The buffer air tank also stores energy to return the piston to the bottom of the cylinder where it will be ready to shoot another bale. Some energy is lost in the recoil system due to cooling and leakage. To compensate for the loss, make-up air from below the piston is allowed to enter the recoil

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1949, as a contribution of the Power and Machinery Division. Authorized for publication as Journal Paper No. J1727 of the Iowa Agricultural Experiment Station, Project 1159.

The authors: J. B. LILJEDAHL and E. L. BARGER are, respectively, formerly research assistant professor and research professor of agricultural engineering, Iowa State College, Ames.

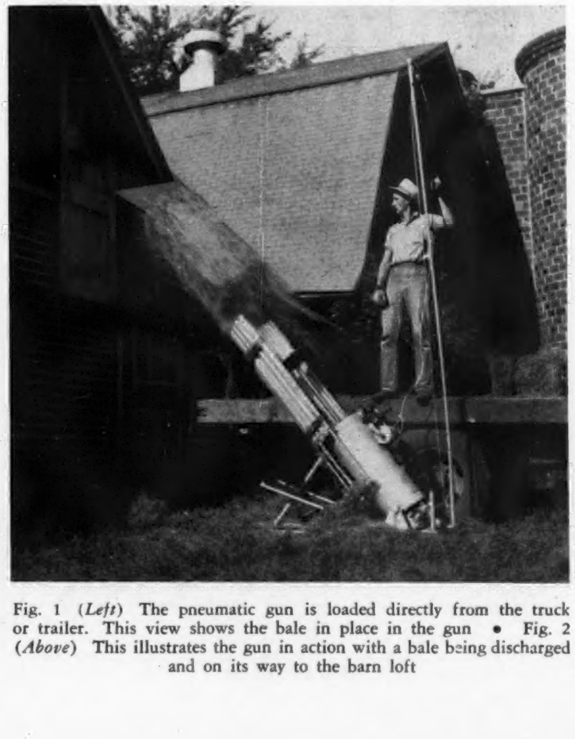


Fig. 1 (*Left*) The pneumatic gun is loaded directly from the truck or trailer. This view shows the bale in place in the gun • Fig. 2 (*Above*) This illustrates the gun in action with a bale being discharged and on its way to the barn loft

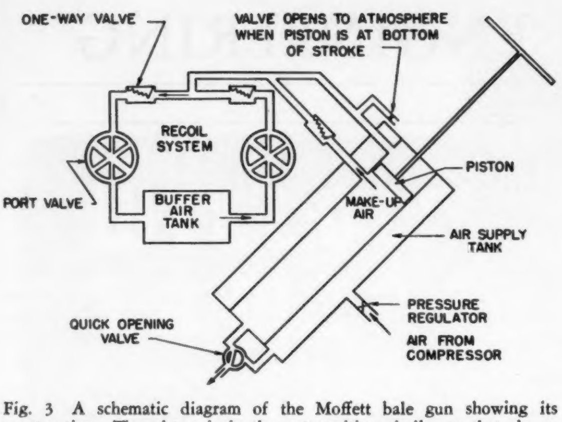


Fig. 3 A schematic diagram of the Moffett bale gun showing its construction. The piston is in the out position similar to that shown in Fig. 2 where a bale is being ejected

system when the piston is at the top of the stroke. To return the piston to the bottom of the cylinder the quick-opening valve at the bottom of the cylinder is released, thereby opening the cylinder below the piston to the atmosphere. The compressed air in the buffer-air tank then forces the piston to the bottom of the cylinder. The rate at which the piston is stopped at the top of the cylinder is regulated by the left port valve. The right port valve regulates the rate at which the piston returns to the bottom of the cylinder. These valves which restrict the flow of air need to be adjusted when the air pressure in the cylinder is changed markedly. The space above the piston is opened to atmospheric pressure by a valve above the cylinder, which is opened automatically by the plate on the plunger when the piston returns to the bottom of the stroke. This completes the cycle, and the gun is ready to shoot another bale when the desired pressure in the air supply tank is reached.

In these tests a two-stage compressor having a displacement of 16 cfm was used. The machine was designed to be used in conjunction with a 21-cfm two-stage compressor, which would have increased the capacity of the gun under some circumstances.

Performance. The rest of this paper will be concerned with the performance of the bale gun. It was tested at Iowa State College under conditions varying from nearly ideal to very impractical.

Projectile curves for a 58-lb hay bale were plotted in order to determine the effect of pressure and angle. These are shown in Fig. 4. The bale, sewed up in burlap to keep its weight constant, was of dry alfalfa hay. These curves could be used to predict the spot where a bale would land if all bales of hay weighed the same. Actually, with only a few minutes of experience, the operator is able to place the bales reasonably close to the desired spot. At 200 psi and at an angle of 60 deg, the bale went 21 ft vertically and 48 ft horizontally. At the same pressure and at a 45-deg angle the bale went 14 ft vertically and 58 ft horizontally. The maximum vertical distance which a bale can be shot would be increased somewhat if the angle was increased. From this information one can predict the gun's performance with barns of different heights and lengths.

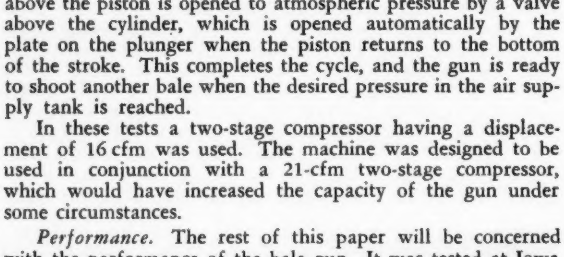


Fig. 4 Effect of angle and air pressure on projectile curves with a 58-lb bale of hay

Table 1 and Fig. 5 compare the bale gun with three other methods of storing baled hay. It was found that when unloading by hand, a three-man crew could unload bales into a ground level shed at a rate of 5.4 bales per minute*. The capacity of this method is fairly good, but the labor expenditure is high. Naturally, this method is limited to low barns

TABLE 1. COMPARISON OF METHODS OF UNLOADING BALED HAY

Method	Bales per minute: Capacity of crew	Bales per minute: Capacity per man
Unloading by hand, 3-man crew	5.4	1.8
Conventional barn fork, 2-man crew	3.2	1.6
Grain elevator, 2-man crew	4.1	2.0
Bale gun, 1-man crew. Door 10 ft high (short duration only)	12.0	12.0
Bale gun, 2-man crew. Door 13½ ft high	7.7	3.9
Bale gun, 1-man crew. Door 21 ft high	2.8	2.8

and sheds, and even then it is still hard work. The conventional grapple fork, which is probably used more than any other method in the midwest, has a low capacity of 3.2 bales per minute with a two-man crew. This is the only practical method, other than slings, which can be used on long barns having no side doors into the mow. It, of course, requires that the barn have a hay fork and track.

A flight-type grain elevator has a somewhat greater capacity of 4.1 bales per minute with a two-man crew, but it is limited to fairly low barns which can be filled from several doors.

The first three methods, which have just been described, will have greater or less capacity than shown depending upon the weight of the bales, and the size and shape of the structure into which the bales are being stored. The values given are averages of samples taken during one haying season.

The next three sets of data in this table show the effect of height on the actual capacity of the bale gun. When the bales were shot 30 ft horizontally through an opening 10 ft above the ground, it was possible to unload at a rate of 12 bales per minute for a short period of time. We found, however, that no one man wanted to work that hard for a long period of time, with the result that labor would limit the capacity of the gun. When shooting into an opening 13½ ft above the ground, the gun would maintain a rate of 7.7 bales per minute if two men were loading it. The gun, which was designed to be operated by one man, can be increased in capacity by using two men when the air from the compressor is not the limiting factor. In the above test two men, without undue physical effort, were able to keep the gun operating at its maximum. The last line in the table shows the capacity of the gun when shooting bales into a door 21 ft above the ground. This is close to the maximum vertical distance to which the bales can be shot with the pressures used. The capacity, which was 2.8 bales per minute, was influenced markedly by the size of the compressor, because in this case there was a waiting period between each bale while the pres-

* Kline, Gerald L.: Harvesting Hay With the Automatic Field Baler. *Unpublished thesis,* Iowa State College Library (1946)

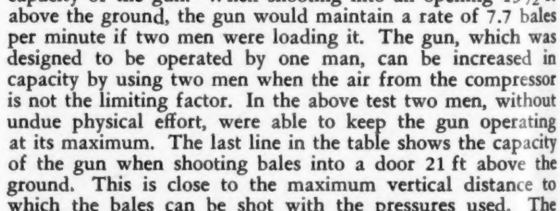


Fig. 5 A comparison of different methods of unloading and elevating baled hay

sure was being built up. If a 21-cfm displacement compressor had been used instead of a 16-cfm compressor, the capacity would have been raised proportionately in cases where the capacity of the air compressor was the limiting factor.

There appeared to be no relationship between the pressure used and the work efficiency of the gun. The average work efficiency of the gun was approximately 21 per cent, which does not include the efficiency of the compressor. A 5-hp gasoline engine is required to operate a two-stage compressor having a 21-cfm displacement at 175 psi. This engine, if used continuously, could be operated at a cost of approximately 10c per hr for gasoline.

Getting the bales into the barn isn't the entire story of course. In barns where space is at a premium, it is necessary to stack the bales. No attempt was made during this investigation to compare these methods of unloading as to the labor required in handling the bales in the barn. In Table 1 and Fig. 4 the labor of stacking the bales was not included.

No labor is required stacking bales when a grapple fork is used in narrow barns if space is not at a premium. The grapple fork distributes the bales lengthwise of the barn but not very much crosswise. When bales are unloaded with a grain elevator or by hand the distributing is done by hand. When using the gun, the bales can be distributed over the entire barn by the operator if the barn has a fairly large door on each side, and if the building is not more than 50 ft long.

Some difficulty was experienced with this experimental model in moving it about. The gun, which is mounted on skids and two small auxiliary wheels, weighs approximately 600 lb excluding the compressor. One man can move the gun on a smooth hard surface; however, in most cases the ground conditions were such that it was necessary to use a tractor or several men to move the gun from one door to another.

The condition of the bales after they were in the barn is an important factor to be considered. It was found that 3.4 per cent of the bales were broken when dropped from a grapple fork. No bales were broken when they were unloaded into the storage structure with a grain elevator or by hand*. Two per cent of the bales were broken during all of the tests with the gun. If the pressure regulator had always been adjusted so that the bales did not go any higher than was necessary to put them in the desired place, the breakage could have been reduced. Obviously if the bales are shot considerably higher than is necessary, there will be unnecessary breakage.

CONCLUSIONS

1 The capacity of the gun was very markedly affected by the height to which the bales had to be thrown.

2 The gun had a lower labor expenditure than the other methods of conveying bales into a storage structure.

3 When the gun was used to shoot bales into low doors, its capacity was greater than the other methods studied.

4 The labor efficiency in handling bales was lower with long barns (over 50 ft) that did not have side openings.

5 If the gun did not have to be moved, it could be operated quite easily by one man.

6 The gun in its present design was difficult to move under most conditions.

The Solaranger

By Ralph R. Parks
MEMBER A.S.A.E.

THIS device was built under the direction of Dr. L. W. Neubauer with data and suggestions furnished by Dr. F. A. Brooks, both of the division of agricultural engineering, University of California, Davis.

The purpose of the instrument is to study the effects of sunlight and shadows in farm building and landscape design. For example, whether to place a building with the true north and south, how high to place windows with respect to roof overhang to keep out the sun in summer and let it in during the winter, and where to place trees to secure maximum shade in summer and minimum shade in winter.

The solaranger is assembled so it can be easily taken apart and transported. It can be set up on any board surface or table where scale models can be shown. It is not intended as a precision device but rather one from which general arrangements can be decided on, and accurate measurements can be calculated from trigonometric computations.

The author: RALPH R. PARKS is extension agricultural engineer, University of California.

The solaranger built by California agricultural engineers

The three adjustments in the instrument allow one to show hourly change of the sun, seasonal variation, and incidence at different latitudes. The hourly change is shown by swinging a light representing the sun around an axis parallel to the earth's axis. The time of day is indicated on a disk which is perpendicular to the axis of the instrument. The seasonal variation by months can be set into the instrument by lengthening the axis which is parallel to that of the earth's and thus simulate the shifting of the earth's position with respect to the sun. The latitude adjustment can be made by changing the angle of the instrument's axis with relation to the surface on which it is fastened. With the "sun's" supporting shaft removed, one can sight down the tube for the height adjustment of the lower standard after the upper one has been fixed in place. Height of the rear standard can be determined from a table furnished with the particular instrument used.

Construction details for the instrument illustrated can be secured from the Division of Agricultural Engineering, University of California, Davis. It is simple to construct and is built largely of ⅜-in tubing, ⅜-in rod and ¼-in rod, welded and bolted together. Some light source is required to represent the sun; a strong light is needed for bright room showing or showing to large audiences. A pen flashlight works well in a darkened room and for small audiences.

A number of special problems can be demonstrated with this instrument. For example, west windows are a considerable disadvantage to a house when the late afternoon summer sun hits them, while south windows are more desirable and can use winter sun yet be protected with overhanging roofs in summer. Contemplated tree plantings and farmstead building arrangement can be studied to take maximum advantage of shade and/or sun on windows and roofs at different times of the day and season. Better advantage of radiation heat in the case of field crops can be taken if more attention is given to the angle at which seedbeds are formed. Early grown truck crops can be given better protection from radiation losses if the angle of paper shields, for example, were more closely studied. These are intended to let in a maximum of radiation heat from the sun and yet give the best cover for reducing radiation losses to the sky. These and other problems that can be discussed with the aid of the solaranger make it a very valuable teaching device.

A New Concept of the Side-Delivery Rake

By B. G. Elliott

FOR many years the hay crop was one of the least mechanized crops of the farmer the world over. The harvesting of hay was one of the slowest, most inefficient and back-breaking jobs on the farm. Then came a period of mechanization; many improvements were made on existing machines, and new machines were introduced for speeding up and reducing the burden of making hay. The methods of handling the hay, however, remained basically the same, and very little work was done toward improving the quality. While the farmer has continually improved his own food and the methods of preserving it, he has not been too concerned about the quality of the feed for his cattle so long as sufficient quantity was produced. Only in the last few years has he become conscious of the fact that he has been leaving a good part of his bank account in the hay field in the form of shattered leaves which contain the major portion of the food value in hay. Of equal importance is the loss of a large percentage of vitamin A and digestible nutrients by curing in the direct rays of the sun.

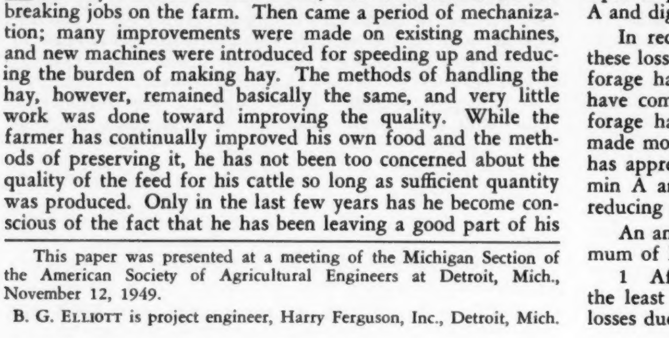
This paper was presented at a meeting of the Michigan Section of the American Society of Agricultural Engineers at Detroit, Mich., November 12, 1949.

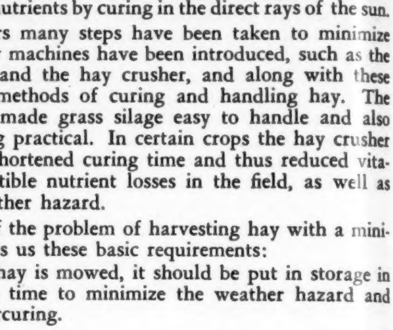
B. G. ELLIOTT is project engineer, Harry Ferguson, Inc., Detroit, Mich.

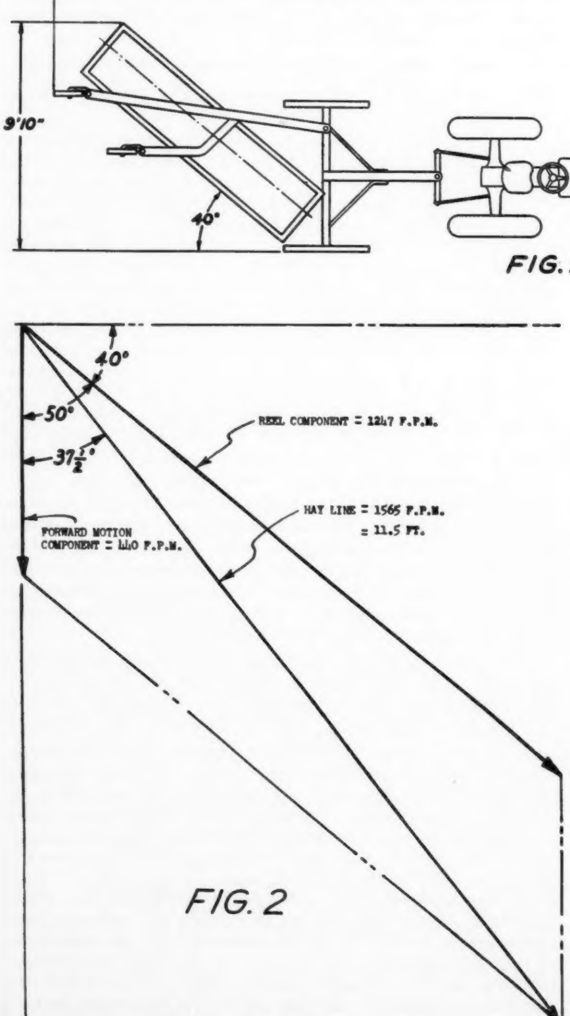
In recent years many steps have been taken to minimize these losses. New machines have been introduced, such as the forage harvester and the hay crusher, and along with these have come new methods of curing and handling hay. The forage harvester made grass silage easy to handle and also made mow curing practical. In certain crops the hay crusher has appreciably shortened curing time and thus reduced vitamin A and digestible nutrient losses in the field, as well as reducing the weather hazard.

An analysis of the problem of harvesting hay with a minimum of loss gives us these basic requirements:

1 After the hay is mowed, it should be put in storage in the least possible time to minimize the weather hazard and losses due to overcuring.







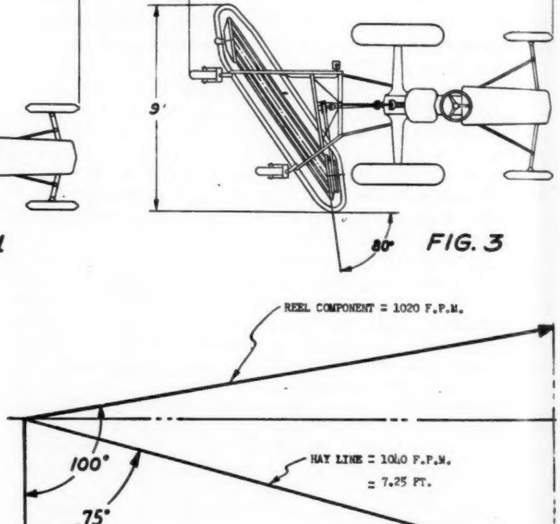


Fig. 1 Conventional side-delivery rake • Fig. 2 Vector diagram of raking action of the conventional rake • Fig. 3 The Ferguson side-delivery rake • Fig. 4 Vector diagram of raking action of the Ferguson rake

2 The leaves should be protected from the direct rays of the sun as much as possible while the hay is being cured, to reduce vitamin A and digestible nutrient losses.

3 To hold leaf loss to a minimum, the hay should be handled in the most gentle manner possible.

Another basic requirement in designing a machine to perform this or any other operation is to build quality and long life into the machine with a minimum of upkeep and repairs and at a price that will enable the job to be done at the lowest

unit cost. If the farmer cannot increase his earning power directly or indirectly by the new machine, it is very unlikely that he will buy one just because it has a new coat of paint and looks better than his old one.

We believe that the proper procedure to follow in the development of a new implement is not to follow blindly the methods by which the job has been done in the past. Instead, the requirements of the job should be analyzed, to determine how it can best be performed. Based on these requirements, a machine can be developed that will perform the job in the best manner possible and produce the highest quality crop at the lowest over-all unit cost.

The Ferguson side-delivery rake is our first step in applying this engineering philosophy in the haying machinery field. We have attempted to build into this rake as many of the desirable features as possible for raking efficiency, speed, ease of operation, low unit cost, and minimum maintenance requirements, for producing the highest quality hay possible. Some of these features are:

1 A new type six-bar reel construction which moves the hay a minimum distance in a smooth and uninterrupted flow to a windrow that is loose and fluffy, permitting good air circulation for drying in the windrow.

2 Toothbars mounted on lubricated and sealed-for-life ball bearings, with bars mounted to spindles on rubber to absorb shock.

3 Spiders and drive shaft mounted on tapered roller bearings, requiring yearly lubrication only.

4 Only seven grease fittings requiring daily attention.

5 Attaches to tractor by Ferguson three-point hitch, plus power take-off, making a compact mobile unit that follows directly the path of the tractor.

6 Lifts by hydraulic control for short 180-deg turns, and is carried on links of tractor in transport.

7 The relation of the rake to the tractor is such that, when the wheels are spread on the tractor, these wheels may be driven in the path of the mower swathboard without running on the hay.

8 The right-hand rake wheel tracks with the corresponding tractor wheels when they are set on 72-in centers. This gives an ideal arrangement for raking off irrigation borders as the right-hand tractor and rake wheels are run along the top of the border.

In making a comparison between the new rake and side-delivery rakes of the conventional reel design, let us first look at a typical rake of the latter. The rake used for this comparison was chosen because it was the most readily available and seemed to be typical. The following data were computed from actual measurements of this rake and might vary slightly for different models or makes of rakes of the same general principle:

Fig. 5 This shows the Ferguson side-delivery rake in action

From the diagram (Fig. 1), it is seen that the reel is set at an angle of 40 deg to the direction of travel. The extreme distance between the end teeth is 11 ft, giving a raking width of 7.05 ft. For simplicity in comparison, a ground speed of 5 mph has been assumed. Breaking this down into feet per minute, gives a ground speed of 440 fpm. The ratio of the ground speed to the peripheral speed of the teeth when in the raking position is 1 to 2.83, or a ground speed of 440 fpm to a tooth speed of 1247 fpm at 5 mph. The theoretical path that the hay follows from the swath to the windrow is the resultant of these two speeds when plotted to scale. A vector-type diagram illustrating this and the path that the hay follows is shown in Fig. 2. Solving this triangle, we find that the hay is moved along a line running 37½ deg to the direction of travel and at a velocity of 1565 fpm. If we consider the hay to be raked the extreme distance for a 7-ft swath, we find that it is moved a distance of 11.5 ft in being transferred to the windrow or 4.5 ft more than the minimum possible distance of 7 ft.

RAKING ACTION ENTIRELY DIFFERENT

For a similar analysis of the new side-delivery rake (represented in diagram Fig. 3), a like raking speed of 5 mph has been assumed. The raking action of this rake is entirely different from that of the conventional rake; however, a direct comparison can be made as to the velocity of the hay and the distance it is moved. The direction of movement of the hay due to the rotation of the reel is 100 deg to the direction of travel as compared with 50 deg for the conventional rake. The vector-type diagram (Fig. 4) illustrates the velocities of the forces acting to move the hay and the magnitude and resultant of these velocities. Again assuming a 5-mph raking speed, we have a ground velocity of 440 fpm. The ratio of the ground speed to the peripheral speed of the teeth in the raking position is 1 to 2.37, or 440 fpm ground speed to 1020 fpm tooth speed. Referring to Fig. 4, the resultant of these two velocities shows the theoretical direction of movement of the hay to be along a line 75 deg to the direction of travel and with a velocity of 1040 fpm. Again considering the hay to be moved the extreme distance in raking a 7-ft swath, we find that it is moved a distance of 7.25 ft, or only about 3-in further than the shortest possible distance of 7 ft.

Going back to the velocity at which the hay is moved when traveling at 5 mph, we had for the conventional rake 1565 fpm and for the new rake 1040 fpm. This means that the new rake can travel at 7.5 mph without moving the hay at any greater velocity than the conventional rake does at 5 mph.

At these two raking speeds of 5 mph and 7.5 mph, with the velocities of the hay equal for the two rakes, the new rake still moves the hay a distance 59 per cent less than that moved by the conventional rake. Looking at this from another point of view, we see from the diagrams (Figs. 2 and 4) that the new rake moves hay an extreme distance of 7.25 ft and the conventional rake an extreme distance of 11.5 ft. Subtracting 7 ft, which is the shortest distance that the hay could be moved in either case, we have the new rake moving the hay an extra distance of 0.25 ft as compared with 4.5 ft for the conventional rake. This means that the conventional rake moves the hay an extra distance equal to 18 times the extra distance it is moved with the new rake.

Summarizing the comparable data on the two rakes, we have (a) the new rake operating 50 per cent faster than the conventional rake for an equal velocity of the hay and (b) the new rake moving the hay a distance 59 per cent less than it is moved by the conventional rake.

One of the greater advantages embodied in the new rake, as we see it, is the raking action of this type of reel. From the moment the hay is first contacted by a tooth, it is swept at a uniform velocity into the windrow, whereas with the conventional rake it is tossed ahead and dropped, to be picked up and tossed again by the next bar of teeth until it finally reaches the windrow. This process is more or less like the procedure sometimes used by our young sons for bringing home a tin can by kicking it along in front of them. Needless to say, the tin can is usually in pretty bad condition by the time it reaches home.

Poultry House Ventilation—Theory and Practice

By H. N. Stapleton and Earle Cox
MEMBER A.S.A.E. MEMBER A.S.A.E.

THE development of a satisfactory solution to the application of ventilation to poultry houses has plagued operators, poultry specialists and agricultural engineers for many years. The ventilating problem is to remove approximately the same amount of water as is supplied to the birds each day, plus the gaseous products of litter decomposition, while maintaining a satisfactory inside temperature in a building of a grade of construction which can be economically supported by the enterprise. In practice, the solution of the problem is complicated by individual management, economics, and the headroom and excess cubage in the structure which are required by the attendant. The scope of application discussed in this paper will be specifically limited to laying houses in which the adult hens range the floor area only. Ventilation of cage houses, brooder rooms, brooder houses, and broiler and roaster plants requires separate and specific treatment.

The considerations which work well in dairy stable ventilation are not applicable to the same degree for the poultry laying house. In the dairy stable there exists essentially a cooling problem, and in the removal of the excess sensible heat, air purity and odors are satisfactorily controlled. That it is a cooling problem is shown by an article by Holmquist(1), which describes the use of a heat pump to heat a farm house by use of waste heat from the dairy barn. Insulation of the dairy structure is provided to control condensation and to prevent floor drafts. Moisture removal is concerned very largely with that produced in the respiration process as the wet litter and manure are usually removed at least once daily. The heat balance equation contains little latent heat. The heat input from the animals is relatively large, usually about 25 Btu per sq ft of enclosing surface. Solar input can be ignored, principally due to the usual solar orientation of the structure.

This contrasts with the laying house in which the principal consideration is a drying operation. Every advantage should be taken of good solar orientation, good air drainage, and reasonable protection from winds which dissipate heat from the structure. Insulation of the structure is provided to conserve heat for the drying operation, and this insulation includes a deep litter which by decomposition can furnish latent heat for the vaporization of the daily water load. Heat input by the birds can be maintained at high level by keeping the population at a high density, even though this may change other management factors and require the use of elevated feeders and equipment. In structures of the same width, that is, approximately 36 ft, the heat input from birds per hour per square foot of enclosing surface will be from one-third to one-fourth that of dairy animals. In a common house, 24 ft wide, it can be expected to be about one-fifth, or from 5 to 6.5 Btu per hr per sq ft. Management of the ventilation system must conserve as much heat as possible. Control of odors and air purity are obtained when the drying is accomplished. The insulation which conserves heat for the drying operation functions also to control condensation. This oversimplification of the problem is for the development of a concept and a mode of attack which permits the development of an independent evaluation of the unknown elements of the single equation. Since there is but one equation, it can be written as: Heat Out = Heat In and it can be expanded to

Wall Loss + Ventilating Air Loss + Latent Heat = Animal Heat + Lamp and Equipment Heat + Solar Heat + Heat from Litter Decomposition

By taking values for some of these elements from handbook and other published information, the values for the remainder may be developed experimentally; and in either design or analysis, the equation permits prediction of probable operating conditions. Handbook data permits the evaluation of the "heat out" side of the equation with a fair degree of accuracy.

The heat input side of the equation is not so readily evaluated. The heat supplied by the birds can be approximated from metabolism studies, but there still remain two factors on the "heat input" side of the equation to be evaluated, namely, solar heat and heat from litter decomposition. Ventilating designers in the past have neglected these two heat sources. The theory seemed to be that since the effect of solar radiation and litter decomposition was unknown it should be neglected, as any heat received from the two sources was so much "velvet".

A poultry house ventilation project is under way at the University of Massachusetts and the results of one year's work have indicated that the heat from solar radiation and litter decomposition is appreciable. The ventilation design was first calculated on the assumption that the solar heat plus the heat from litter decomposition would supply part of the heat of vaporization. It was assumed that it would be sufficient to vaporize any water introduced into the pen which was not vaporized by respiration. It was also assumed that no sensible heat was supplied by solar heat or litter decomposition. On this basis it was calculated that a 10-deg differential could be held between house air temperature and outside temperature. Since the mean daily temperature in the Amherst, Mass., area during December, January, and February is near 25 F, this meant that no freezing would occur in the house unless prolonged cold spells occurred.

The experimental pen selected was the end one of four 24 x 24-ft pens on the lower floor of a two-story house. The theoretical calculations assumed no heat transfer between adjacent pens and no heat transfer through the floor. The walls of the pen contained shavings as insulation between 2 x 4-in studs. The ceiling of the pen was covered with about 6 in of litter in the pen immediately overhead.

The sensible heat produced by the birds was taken as 52(1.00 -0.079) 140=6705 Btu per hr. These values are for 140 6-lb birds at an environmental temperature of 35 F. About 52 Btu per hr are produced by a 6-lb bird, and of this 0.079 Btu of the total is in latent form(2).

Neglecting the sensible heat to be obtained from litter decomposition and solar radiation, the net heat available for ventilating became 6705 − 1090 = 5615 Btu per hr. This figure was used to determine the air movement and to arrive at the amount of water removal per day. The amount of water consumed by the birds was taken to be 45 lb per 100 birds(3), or 45 × 1.4 = 63 lb.

It was considered that fans powered by electric motors would offer the best means of reliable air control with a small labor requirement. Accordingly, two 9-w motors were staged in series in a 9-in diameter stove pipe. The fans were two blade, 8½-in in diameter. The capacity, with no damper restriction, was 322 cfm with power to both motors and 265 cfm with only the inner motor running. The inner motor was wired for continuous operation and the outer was set on thermostat to have power supplied above an exhaust air temperature of 35 F.

The fan installation began operation on December 14, 1948, at a time when the litter moisture content was above 28 per cent, wet basis. This represented a moisture content 4 per cent higher than any of the other three pens on the first floor. The fan was operated continuously from December 14 until spring and periodic litter samples were taken. The moisture content in the pen rose from 28 per cent to a high of 30 per cent and began falling after February 14, 1949. The windows were kept closed during this period. Handbook values for

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* Numbers in parentheses refer to the appended bibliography.

crack infiltration indicated that when the fan was not in operation, the air infiltration through the cracks around the windows would be about 250 cfm. Therefore, it was considered that additional air intakes were unnecessary.

The results obtained show a much less favorable relative humidity relationship than assumed, but an increased differential temperature which gave a higher rate of water removal than calculated. The differential temperature was 18.8 F for two months from December 14, 1948, to February 14, 1949. The water removed from the pen per day was taken at 63 lb since the litter moisture content increased only slightly. The transfer of moisture from the adjacent pen made the transfer of moisture through the fan about 50 per cent above the 63 lb amount. Experimental results gave 7250 Btu per hr removed in the exhaust air from the experimental pen. The pen losses on an 18.8 F differential were 2050 Btu per hr. The total sensible heat losses then were 7,250+2050=9,300 Btu per hr. The total sensible heat from the birds was 52 (1.00−0.13) 140= 6,334 Btu per hr. The sensible heat is taken at an environmental temperature of 48.5 F, at which point the latent heat is 13 per cent of the total(2). This plus the heat from lights gave a total heat production of 6574 Btu per hr. However, the difference between incoming and outgoing air showed a total of 9,300 Btu per hr as being removed from the pen. Obviously such additional heat had to come from solar radiation and litter decomposition.

The solar radiation was determined from readings at the Blue Hills Observatory located at Milton, Mass. These showed a total of 1680 Btu per hr actually incident on the outside surface of the glass. This is based on an average of 250.1 g-cal per sq cm per 24 hr for the period December 14, 1948, to February 14, 1949. Of the 1680 Btu, part was considered to be absorbed by the glass, part transmitted through the glass, and part reflected. Handbook sources indicate that, for the prevailing conditions, 1462 Btu per hr would have penetrated a clean glass. Light meter readings were used to determine the reduction in transmissivity due to dust. These gave a final determination of 1276 Btu per hr input from solar sources. Allowing 1276 Btu per hr for the solar radiation heat input into the pen, there remains 9,300−6574−1276=1,450 Btu per hr as sensible heat from litter decomposition.

TABLE 1. POULTRY HOUSE VENTILATION CALCULATIONS AND EXPERIMENT RESULTS

	Area, Sq ft	U factor	Loss, Btu/hr deg F
Exposed wall	496.3	0.083	41.3
Ceiling	576	0.034	19.7
Glass	43.7	1.1	48.
		Calculated	Experimental
Floor area, sq ft		576	576
Bird population		140	140
Airflow, cfm		267	322
$T_I - T_o$, F		10	18.8
T_I, mean daily, F		35	48.5
T_o, mean daily, F		25	29.7
RH_I, mean daily, per cent		90	77
RH_o, mean daily, per cent		70	83
Heat in, Btu per hr (sensible + latent)			
Birds Sensible		6,705	6,334
Birds Latent		575	946
Litter Latent		1,013	1,834
Litter Sensible		0	1,450
Solar		1,000	1,276
Lights		0	240
		9,293	12,080
Heat out, Btu per hr (Sensible + latent)			
Wall loss		1,090	2,050
Ventilating Latent		2,588	2,780
Ventilating Sensible		5,615	7,250
		9,293	12,080
Water removed, lb per 24 hr		58.2	63.0

Where

U = Btu per hr per deg F per sq ft
I = Inside
O = Outside
T = Temperature
RH = relative humidity

Since the above analysis has considered only the sensible heat, it is of interest to note the latent heat sources. The water vapor given off in respiration constitutes only a small part of the total water which entered the pen. Since the litter moisture content of the ventilated pen remained nearly constant, it is assumed that all of the 63 lb of water given the birds per day moved through the fan. The latent heat is 52× 0.13×140=946.4 Btu per hr. Taking heat of vaporization at 1044.7 Btu per lb, for a skin temperature of 86 F, the water given off through bird respiration is 946.4÷1044.7=0.906 lb per hr=21.7 lb per day.

Assuming that the remainder of the water, 63−21.7, or 41.3 lb, enters the litter as a liquid, heat must be supplied to it to vaporize it. The litter temperature in the experimental pen is not known. However, the least amount of heat which could have been supplied was that corresponding to the heat of vaporization at the environmental temperature of 48.5 F, namely, 1065.8 Btu per lb. On this basis 41.3÷24×1065.8= 1834 Btu per hr required. The heat balance indicates that this could have come from no other source than from litter decomposition. Table 1 shows original calculations and experimental results.

Table 1 indicates that in this case the heat from litter decomposition comprised about 27 per cent of the total heat on the heat input side of the heat balance equation and over 45 per cent as much as was supplied by the birds. Such an important heat source should not be neglected. Further experiments may show how to increase this value.

In addition to data that indicate the importance of litter decomposition, other data gave indications of the best place to locate the fan. The fan location was kept in the droppings pit, but hygrothermograph recordings were made near the ceiling and near the floor at both the front and rear of the house. The recordings showed that, if the air conditions did not change after fan installation at any instrument location, then the fan location to give the greatest amount of water removal for a given amount of heat removal was near the floor in the droppings pit. The instruments indicated nearly a constant vapor pressure throughout the house. Also a study of the psychrometric chart indicates that the wettest location, even though it may be the coldest, is the proper one for the condition of constant vapor pressure. If no droppings pit is used, it is felt that a compromise must be made. The fan intake should be close to the wettest place in the house and also in the wall opposite the greatest glass exposure.

The collected data also showed that, for any given period of time, the differential temperature between house inside temperature and outside temperature was essentially a constant. On the basis of the above results, a system for ventilating poultry houses is being proposed and cooperative projects with interested poultrymen is being encouraged.

Fig. 1 is a chart from which required air flow can be determined. It is based chiefly on house differential temperature, which is a factor readily measured. This groups the effect of heat from birds, solar radiation, and litter decomposition, thereby evaluating the entire heat input without estimating single items. In using the chart, one has to take outdoor temperature readings and readings inside the building when the birds are in it. An average of readings taken at 7 a.m. and 2 p.m. for 3 or 4 days should be adequate. This will determine the house differential, which is nearly constant for a fixed number of birds.

Secondly, a determination must be made on the losses due to air infiltration. Air moves in and out of the cracks in the building, particularly through window cracks. Handbook values for crack infiltration on an average double-hung window give 7 cu ft per ft of crack per hour when the wind velocity is 5 mph. This figure becomes 21 cu ft when the wind velocity is 10 mph. Other figures indicate that as the wind velocity doubles the air infiltration is cubed. The infiltration

rate together with the length of window crack gives the amount of infiltration air per hour which must be heated. It is assumed that all of this is heat loss, for even though there may be a reduction in heat loss because of condensation on the windows, this heat is given up to a glass surface which has a high coefficient of heat transfer. Therefore, heat from condensation is rapidly dissipated to the outdoors and can have little benefit on raising the temperature of the main mass of indoor air. For this reason, in using the chart, the value of ventilating air moving through the building is made equal to the amount of infiltration air before any change in indoor temperature is made. Then the air flow (cfm), whether by infiltration or ventilation, plus the house differential gives a point on Fig. 1.

In using Fig. 1, the third and last determination is that of the heat loss through the walls and ceiling of the building itself. This can be readily determined from the thermal characteristics of the materials in the building. The heat balance equation is no longer Wall Loss + Ventilating Air Loss + Latent Heat Loss = Bird Heat + Solar Heat + Heat from Litter Decomposition of which two factors are unknown, but becomes

$$(C+QS)\ (T_I-T_o)=\text{Heat Out}=\text{Heat In}$$

where C = heat loss through walls and ceiling, Btu per hr per F per 100 birds

T_I = Temperature inside, F

T_o = temperature outside, F

S = specific heat of air, Btu per cfm per deg F

Q = quantity of infiltrating or ventilating air, cfm per 100 birds.

Then a line can be drawn through the previously determined point. This line should be parallel to the curve on the chart which has the proper value of C.

The plot of "cfm" vs. "differential temperature" in Fig. 1 is based on a 100-bird unit having a sensible heat production of 6500 Btu per hr plus sufficient latent heat production to vaporize all outgoing water. Several lines could have been drawn for each value of C and varying amounts of heat production. These would have been parallel to the original lines, but the overlap on various C value lines would have created confusion. The person landing in "no man's land" when using the chart, both in regard to C values and heat production within the house, can sketch in an interpolated curve.

The equation indicates three variables and therefore the poultryman has a choice of decisions in order to regulate temperature and remove water from the house. He can change the number of birds in the house to vary $(T_I-T_o)=C$, he can reduce the C value of the building by adding insulation, or he can vary the amount of ventilating air. However, he still must move sufficient air through the house to remove about 45 lbs of water per day per 100 6-lb birds(3). This 45-lb water line is indicated on the plot of "water out" vs. "cfm". It seems evident that since this amount of water entered the house that it must all be removed to maintain dry litter. That it will be given up to ventilating air at 35 F and 80 per cent relative humidity is borne out by figures from the U. S. Forest Products Laboratory. These figures show an equilibrium shavings litter moisture content of less than 17 per cent for the above conditions. Litter at this moisture content would create no problem.

As an example of the use of Fig. 1, suppose that a poultryman lives in a region such as Amherst, Mass. where the mean temperature for the coldest winter months is 25 F and the relative humidity is 70 per cent. It seems probable that he would wish to keep a house differential temperature of at least 12 F as a safeguard against freezing in the house. The horizontal dotted line in Fig. 1 at the differential temperature of 12 deg indicates the desired figure. He then may vary only the items C and Q in the heat balance equation, $(C+QS)\ (T_I-T_o)$ = Heat Out = Heat In, for he has chosen $(T_I-T_o)=12$ F. It is then necessary to erect a series of vertical lines to show the cfm per 100 birds for the various values of C. Note that the upper end point of each vertical line must be above the 45-lb water line and the lower end point must be on or above the 12-deg differential temperature line.

From these vertical lines one sees that this poultryman could use any of the following combinations of C and cfm to maintain a 12 F house differential and yet remove about 45 lb of water per day per 100 birds:

C	cfm	Water removed, lb per day
100	230	45
50	298	51

Once the differential temperature is established, C values can be decreased by adding insulation to the building, by increasing the bird population, or by the use of supplemental heat. For example, the house at the University of Massachusetts had a calculated wall loss of 109 Btu per hr per deg F. Since this was for 140 birds, the C value was $109\div1.4=78$ in even figures. By adding 50 birds to give about 3 sq ft per bird instead of 4 sq ft, the C factor becomes $109\div1.9=57$. Of course, increasing the pen population may also necessitate elevating some of the equipment in the house.

Using insulation alone to obtain the same decrease in C factor requires a new value in average wall U factor of $57\div78$ of the beginning wall U factor. The beginning average wall U factor was $109\div1080=0.101$ Btu per hr per sq ft per F. The new factor would then be $0.101\times57\div78=0.074$ Btu per hr per sq ft per deg F. This means that the resistivity was increased from $1000\div101$, or 9.9, to $1000\div74$, or 13.5. This increase in resistivity is 3.6 or is equivalent to the addition of more than one inch of insulating board. The poultryman arrives at the same C factor either by increasing the density of population or by (Continued on page 122)

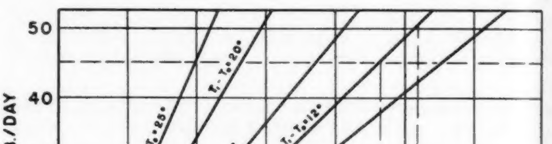

Fig. 1 Air flow chart. In plotting cubic feet per minute vs. differential temperature, outdoor air is taken at 25 F and 70 per cent rh (relative humidity). Wall U factor versus differential temperature is plotted for outdoor air at 25 F and 70 per cent rh, and also for O F and 70 per cent rh. Indoor air is taken at 80 per cent rh. Film conductance is taken at 1.65. Figures are for 100 6-lb birds

Poultry House Ventilation

By J. H. Oliver

MEMBER A.S.A.E.

THE number of articles published on the subject during the past two years indicates continued and growing interest in poultry house ventilation. There is, however, considerable variation in the recommendations of the volume of air required to adequately ventilate a poultry house. This is understandable when one realizes that a difference in relative humidity of 10 per cent between one location and another may easily increase the air flow requirements by 50 per cent to remove the same amount of moisture. Poor insulation or lack of insulation in the poultry house may make almost useless what otherwise would be an excellent ventilating system.

In this article I propose to show the air flow required to maintain dry litter under average winter conditions of 70 to 80 per cent relative humidity and mean temperatures of 10 to 30 F where a well-insulated house is provided. It will easily be seen that it is impossible to ventilate an uninsulated house adequately and still maintain above freezing temperatures in the house at the same time.

Before going into this in detail, let us state the real objectives of poultry house ventilation, as follows:

1 To maintain dry litter and a dry house by removing daily the excess moisture from the house.

2 To reduce labor by eliminating the necessity of opening and closing windows or ventilators one or more times a day.

3 To make the house more comfortable during the hot summer months.

Following are some advantages which are by-products of the above objectives:

1 Maintaining a low relative humidity in the house prevents the absorption of moisture from the air by the litter. Most litter material will remain relatively dry where the relative humidity of the air next to the litter is 80 per cent or less, and will still be quite serviceable where 90 per cent relative humidity prevails part of the time.

2 Dry litter makes possible a saving in labor and material by eliminating the necessity of changing the litter more than once a year.

3 Dry litter and fresh dry air combine to reduce the spread of disease germs. Sanitation is improved and clean eggs generally result.

4 A relatively constant temperature is maintained in the house where thermostat controlled electric fans are used, minimizing the wide fluctuations of winter weather.

5 A dry house increases the useful life of the house itself and the poultry equipment inside it.

6 During summer months when the litter is quite dry, a ventilating system helps to remove the dust from the air, again helping to minimize the disease problem.

Most of the articles written on poultry house ventilation have described very well the arrangement and location of fans(1)*, inlet ducts, how well the house should be insulated(2), etc. What I propose to show in this article is that in certain locations, that is, where the average mean temperature during the winter months is 20 F or higher and where the relative humidity is 70 per cent or less, fan ventilation can keep the house dry; and that where the relative humidity is above 80 per cent or the mean temperature is much below 20 F, supplemental heat must be added at least a portion of the winter if dry litter conditions are to be maintained.

The values of 20 F mean temperature and 70 per cent relative humidity have been chosen to be representative of average winter temperatures in the northeastern United States(3). A second set of charts is included to show what results can be obtained where the average relative humidity is 80 per cent as in our north central states.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

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* Numbers in parentheses refer to appended bibliography.

In order to keep the problem as simple as possible and yet make it applicable to any larger size house, I have chosen a small house as follows:

1 A well-insulated house with 400 sq ft of floor area, approximately 20 x 20 ft, housing 133 Leghorns or 100 heavy breed hens. With this well-insulated house, the heat loss has been calculated to be 100 Btu per hour, or 2400 Btu per day per degree Fahrenheit differential between inside and outside temperatures. Such a house would have walls and ceiling insulated with at least 4 in of shavings or equivalent insulation and would have storm sash on the windows.

2 The amount of moisture which must be removed from the house each day is fairly well established. Repeated tests by leading college poultry departments(4), reliable textbooks(5, 6) on good poultry management, and personal observations have shown that 6 gal of water per day is required to satisfy 100 heavy breed hens which are laying well. Of this 6 gal, that is, 50 lb of water, approximately 5 to 6 lb are removed in the eggs gathered. The balance, approximately 45 lb of water, must be removed by ventilation, of which about 9 lb are given off by the hens breathing, the remainder, 36 lb, is contained in the excreta. In addition to this, any moisture that comes in with the ventilating air must also be removed from the house, so that the maximum relative humidity in the house never exceeds 90 per cent and preferably should be kept below 80 per cent.

3 Heat is the limiting factor in poultry house ventilation. Approximately 217,000 Btu are contained in the 32 lb of feed fed the 100 heavy breed or 133 light breed hens per day (109 g per day per 4-lb hen)(7). Of this amount, it is estimated that each 4-lb hen produces a total of 60 Btu per hour(7)i.e., 192,000 Btu total for 133 4-lb hens or 100 heavy breed hens per day. The 25,000 Btu balance accumulates each day in the litter where, under deep litter conditions, decomposition and bacterial action liberate at least part of this heat each day.

At least another 1000 Btu are added by the morning and evening lights in the house.

We can also expect to benefit from an average of 3 to 5 hr of sunlight per day(3).

From all sources, we can estimate that a total of at least 194,000 Btu are available for vaporizing the water and heating the ventilating air.

4 To vaporize the 45 lb of water which may enter the house at 40 to 50 F, an average value of 50,000 Btu will be used. This will be discharged from the house as latent heat. The balance, 144,000 Btu, is the sensible heat available for heating the air.

5 Calculations will cover the outdoor temperature range from 0 to 40 F with relative humidities of 70 and 80 per cent.

Calculations. The house losses in Btu per day and the sensible heat available for ventilation in Btu per day are shown against differences between house temperature and outside ambient temperature. These are as follows:

Differential between house and outside ambient temperature	House losses, Btu per day	Heat available for ventilation Btu per day
0 F	0	144,000
5 F	12,000	132,000
10 F	24,000	120,000
20 F	48,000	96,000
30 F	72,000	72,000
40 F	96,000	48,000

For example, with a differential temperature between the inside and outside of the poultry house of 10 F, say, 25 F outside and 35 F inside, there is a house loss per day of 24,000 Btu, leaving 120,000 Btu available to heat the moist air leaving the house.

Since heat is the limiting feature in poultry house ventilation, all calculations will be based on heat available under different temperature conditions.

The amount of heat and water contained in the air entering and being discharged from the house can be obtained by referring to psychrometric charts. Thus by subtracting, we can obtain the amount of heat added to each pound of air leaving the house and, dividing this into the total heat available as outlined above, obtain the maximum pounds of air which can be heated per day.

This weight of air times the gain in moisture gives the total water removed each day from the house. Referring to a psychrometric chart with the outside air at 25 F and 70 per cent relative humidity, this air has 8.2 Btu and 14 grains of water per pound of dry air. Now let's assume that this air is exhausted from the house at 35 F and 80 per cent relative humidity. The air leaving the house then would carry 12.1 Btu and 24 grains of water per pound. Thus each pound of air exhausted from the house would carry with it an increase of 3.9 Btu and 10 grains of water.

Dividing the 120,000 Btu available with a 10 F differential by 3.9 Btu for each pound of air exhausted from the house shows that we can exhaust 30,700 lb of air per day, which should carry with it 307,000 grains or 43.8 lb of water. At 35 F and 80 per cent relative humidity, one pound of air occupies 12.53 cu ft. Thus to exhaust 30,700 lb of air per day would require a continuous rate of 267 cu ft of air per minute.

Under the above conditions, 43.8 lb of water will be removed, leaving 1.2 lb remaining in the house each day. The litter will have to absorb this or the air flow and moisture removal can be increased, which will produce a slight drop in the house and discharge temperature.

The results can be seen by referring to the accompanying charts. Fig. 1 shows the poultry house temperature that will result under different levels of air flow with outside ambient temperature from 0 to 40 F at 70 per cent relative humidity, and with the air being discharged from the house at 90 per cent relative humidity.

Figs. 2 and 3 are more typical of our warmer north central states where the air enters the house at 80 per cent relative humidity and leaves the house at 80 per cent (Fig. 2), or at 90 per cent relative humidity (Fig. 3).

The next three charts show the amount of water removed per day from the house for various conditions of outside temperature and humidity with different levels of ventilation, and also the temperature that will result in the house.

Referring to Fig. 4, where outside air is at 70 per cent relative humidity and air is being exhausted from the house at 90 per cent relative humidity, by following the 25 F line to where it crosses the 300 cfm line, it is seen that the poultry house temperature should be 33.5 F and that 54 lb of water will be removed each day. Since that is more water than is put in the house each day, if this rate of air flow continues, the relative humidity will drop until a balance is reached.

Fig. 5 shows that the balance is reached when the relative humidity of the air leaving the house equals 80 per cent at 300 cfm, and when the outside ambient air has a temperature of 25 F and a relative humidity of 70 per cent. Thus, 45 lb of water are discharged each day, resulting in a house temperature of 34 F.

For lower outside temperatures and the same rate of air flow, the house temperature will drop and less water will be removed. Moisture will accumulate in the litter and the relative humidity in the house will rise. Similarly on days of high outside temperature, more water will be removed with the higher house temperature. Actually this cycle repeats every day with cold nights and warmer days.

Thus for these regions where winter temperatures average around 20 to 25 F and 70 per cent relative humidity, provision should be made to ventilate poultry houses at the rate of 300 cfm per 100 heavy breed hens (3 cfm per hen) if dry litter is to be maintained. Sufficient moisture will not be removed when discharging at 80 per cent relative humidity at rates as low as 1.5 to 2 cfm per bird. However, an air flow of 1.5 to 2.0 cfm per bird will be about adequate if the relative humidity is allowed to rise to 90 per cent, although the litter will be much damper.

For those regions where winter weather averages 80 per cent relative humidity, Fig. 6 shows that 3 cfm per bird will remove almost 47 lb of water per day, when the air is discharged at 90 per cent relative humidity with a 25 F outside temperature, and still have 34 F temperature inside the house.

It can be readily seen that as the outside temperature rises the difficulty of removing the moisture is very materially re-

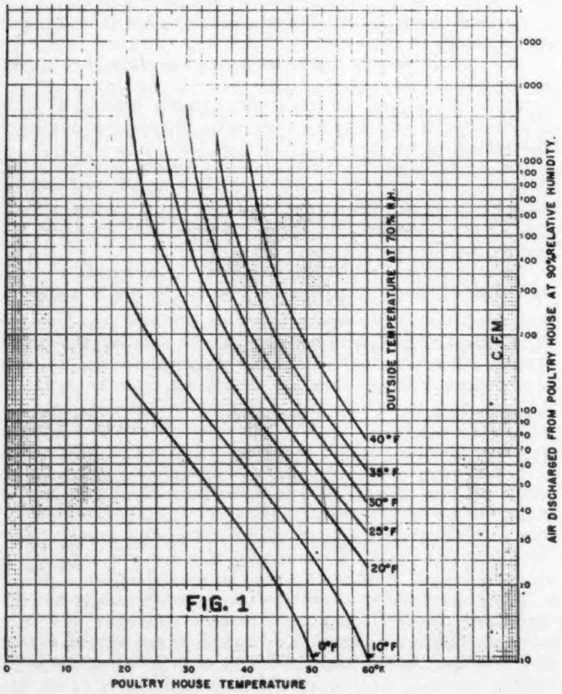

FIG. 1

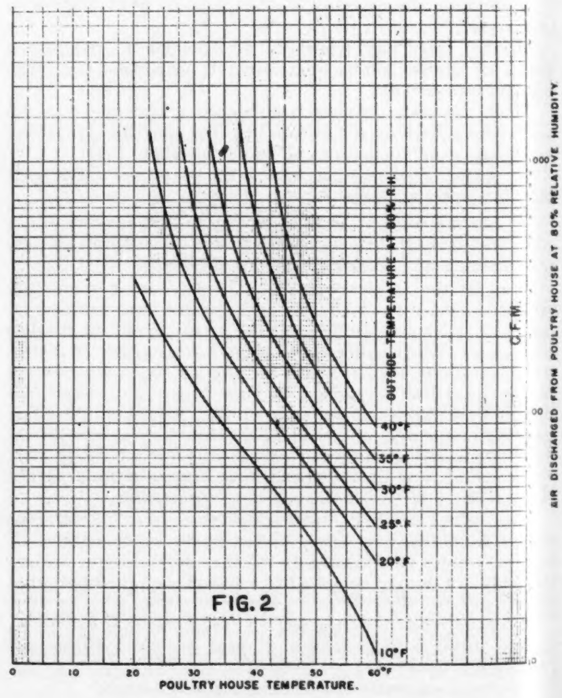

FIG. 2

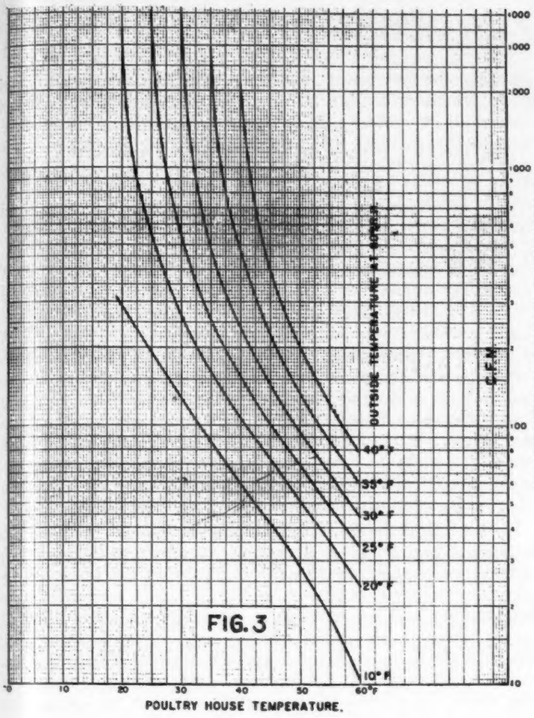

FIG. 3

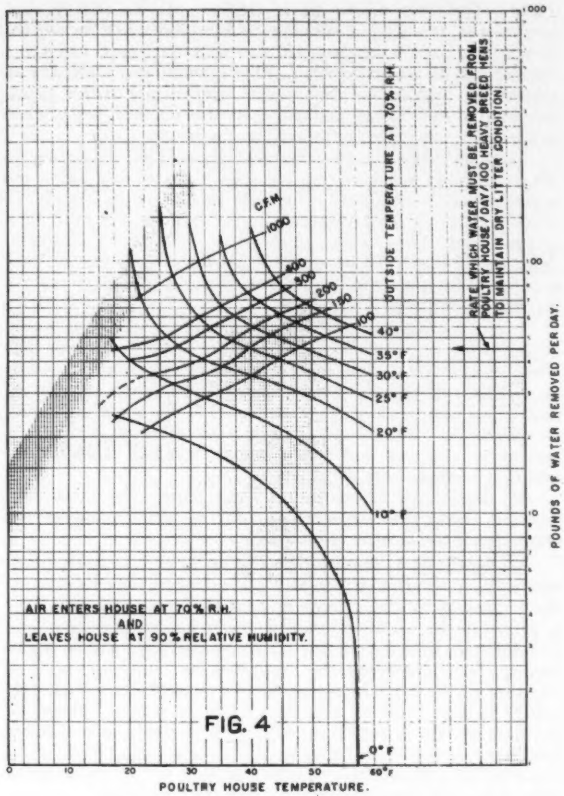

FIG. 4

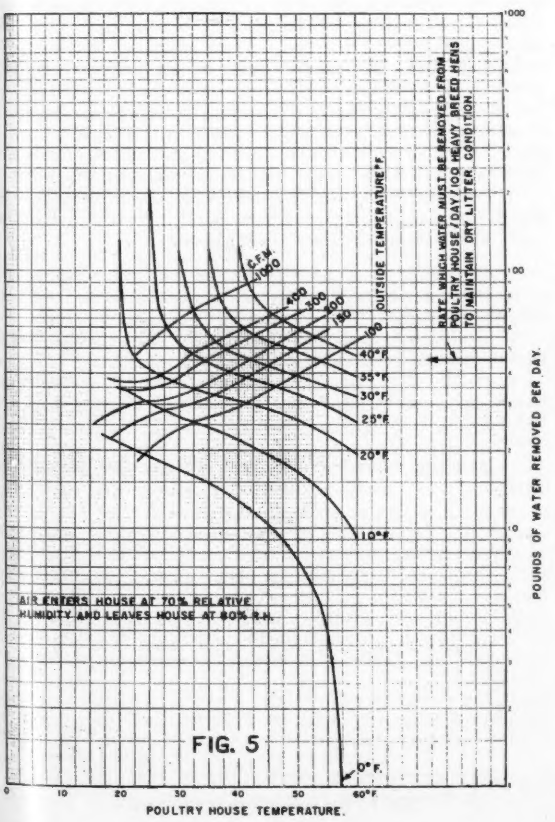

FIG. 5

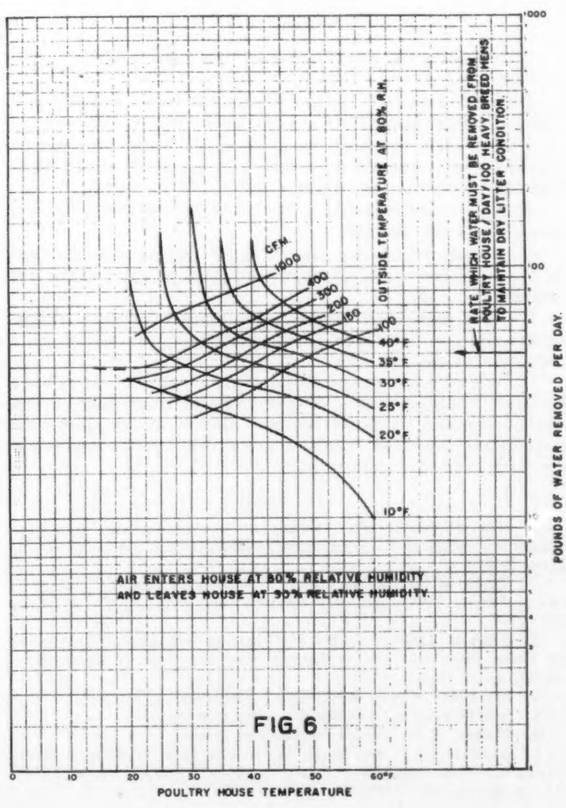

FIG. 6

duced. This fact allows us to do one of two things: (a) operate the fan with a thermostatically controlled two-speed motor, or (b) if a single-speed fan motor is used, provide a damper which can be operated either manually or with a small solenoid to reduce air flow when temperature drops below freezing in the house, and to open the damper wide when temperature rises above freezing in the house.

Thus relatively constant temperature will be maintained in the house, and while during the cold parts of the day some moisture will accumulate, when the sun shines or during the warmer part of the day more moisture will be removed than accumulated. Thus over a 24-hr period or a period of several days, equilibrium will be reached, provided sufficient air flow is maintained while the temperature is warm enough to remove the excess moisture.

From an examination of the accompanying charts it would appear that fan capacity should be at least 3 cfm per hen when temperatures are high to remove as much moisture as possible. When the outside temperature drops and the inside house temperature decreases to 35 F, the air flow should be reduced to 1 cfm per bird where zero or below is common, and to 1.5 cfm per bird where winter weather temperatures seldom go below 10 to 20 F.

For short dips below zero we can expect the house and litter to contribute considerable heat to help maintain the temperature at or near freezing.

No details as to fan location and air inlet have been given. However, it seems that the best place from which to exhaust the air and moisture is from or near the droppings pit. This is probably the point of greatest moisture concentration and it is desirable to draw the dry air across the litter first to maintain dry litter and across the droppings last, since an excess of moisture in the droppings pit will not create the problem presented by wet litter on the floor. Unless a good automatic watering system is available, it may be desirable to suspend a heat lamp over the water fountain to help keep the litter in this area dry. It will also prevent freezing of the water fountains, provided other means have not been utilized.

CONCLUSIONS

1 All the water entering the house must be removed daily — about ½ pint per hen.

2 Heat must be conserved by adequate insulation if above-freezing temperature is to be maintained in the house.

3 A poorly insulated or uninsulated house can be ventilated by increased air flow, but with an inside temperature maintained only a few degrees above that outside.

4 Overventilate when temperature in the house is high, using 3 to 4 cfm per bird.

5 Reduce ventilating rate by speed reduction or dampers to 1 or 1.5 cfm per bird when temperature drops below the desired minimum.

6 This ventilation rate is approximately 1 cfm of air per square foot of floor area at the high rate and ¼ cfm as a minimum at the low rate.

7 Where mean temperatures of 10 F or lower, or relative humidity averages above 80 per cent for more than a few weeks — beyond the point at which deep litter can absorb the accumulated moisture — supplemental heat will be required if dry litter is to be maintained.

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Poultry House Ventilation

(Continued from page 118)

increasing the insulation. In other words, many poultrymen can reduce the structure cost per bird by adding more birds rather than by building more structures or adding more insulation to the existing structures. The above figure of 3 sq ft per bird is conservative as instances are known where the bird density is 1.5 to 2 sq. ft per bird.

It is believed that the foregoing chart, Fig. 1, is a tool which will determine the ventilation requirements for a building. It also provides information on the wall *U* factor needed to prevent condensation. This condensation line is plotted as a function of differential temperature for outdoor temperatures of 25 F and of 0 F. This shows that a *U* factor of 0.31 or less is sufficient to prevent frost when the inside air is 25 F and 80 per cent relative humidity, and the outside temperature is 0 F. It appears that the wall *U* factor need be only slightly lower than that for a double-glazed window, that is 0.45, in order to prevent wall condensation in an area comparable to Amherst, Mass. It may be that condensation trouble has been caused by failure to move sufficient ventilating air where designers have neglected the heat obtained from solar radiation and litter decomposition.

In theoretical design one is always faced with the problem of condensation on glass areas. In an effort to reduce such condensation a sheet metal strip was used at the front of the experimental house as shown in Fig. 2. This kept warm air from striking and condensing on the windows. It is believed that by taking in air on the window side of the building that such cold air helps to blanket the windows and reduces condensation. Because of the low velocities it was difficult to track the air at all points. Indications are that the circulation is as shown in Fig. 2. The difference in air temperature on the two sides of the sheet was at least 5 F.

SUMMARY

It is considered that Fig. 1 provides information from which the ventilation requirements of poultry houses can be readily determined. It is necessary to measure the house differential temperature, window crack length and estimate the house *U* factor to determine which curve applies to a particular house. The choice of a new differential temperature determines how much air may be circulated. If this is insufficient to remove 45 lb of water per 100 birds, then more birds must be added or the house construction must be improved.

It is believed that the fan should be located as shown in Fig. 2 and that, if a thermostatic control is used, provision be made so that some air is always exhausted.

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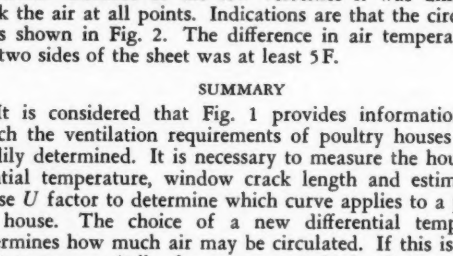

Fig. 2 Air flow in experimental pen

Fundamentals in Conservation Research

By M. L. Nichols
FELLOW A.S.A.E.

THE primary objective of the present national program of research in the field of soil and water conservation is to develop the technical basis for a sound practical program for the farms and ranches of the nation. The application of conservation science to these lands is well under way in some 2200 conservation districts, in numerous flood control projects, and in extensive drainage and irrigation enterprises. The program of research is therefore largely concerned with rendering a direct and immediate service in solving or helping to solve rather urgent problems arising in field operations, and at the same time developing the basic or fundamental principles to permit a wider application than can be secured from empirical testing. There is one point that should constantly be kept in mind: the fundamentals with which we are concerned are the fundamentals of practical field problems. Academic research disconnected with applications of course has contributed much of value to our progress, but it is not the job with which we are concerned.

Conservation of soil and water cannot be achieved without considering practically all of the arts and sciences involved in agriculture. The general field in which we are working includes a complex of physical, biological, and economic sciences so interwoven that any material change in one usually effects a material change in the others which should be carefully considered before extensive application can be undertaken.

The primary consideration in soil conservation is, of course, the soil itself and its reaction to climatic, biologic, and hydraulic forces under various land usages. There is sufficient written information about soil to fill many libraries, but when we come to search for the precise information which the engineer needs for application to specific locations and specific jobs there is really very little of a quantitative nature available. There are two very good reasons for this. First, the word "soil" itself is a generic name covering a great variety of materials in an infinite number of conditions. Second, the condition of any soil at any specific location varies with time and in accordance with previous uses. Cecil sandy loam, for example, varies from a practically impermeable state to a condition of high permeability. Its natural swelling and shrinking on wetting or drying, heating or cooling, freezing and thawing, its reaction to the complex changes brought about by plant microorganisms and animals such as earthworms, its reaction to tillage or trampling by animals or vehicles at various moisture contents all affect permeability and other features with which we are concerned. The researcher must therefore recognize the dynamic nature of the soil, which determines not only the qualitative but also the quantitative results to be expected from any manipulation or treatment.

Two broad classes of basic information must be developed before more efficient conservation practices can be developed, accurately evaluated, and applied to the land. The first class is knowledge of the forms of manifestation, natural distribution, intensity, frequency of occurrence, etc., of the natural forces and resistances to be dealt with, as well as the range of variation within which each can be manipulated. The second class of information deals with the analysis and evaluation of the effects and interactions of forces and resistances. These supply the basis on which conservation measures are developed and evaluated. They also furnish the criteria upon which conservation practices must be adjusted and fitted to meet the specific requirements of local climatic, soil, and vegetative conditions.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1949, as a contribution of the Soil and Water Division.

The author: M. L. NICHOLS is chief of research, Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

We have attempted to catalogue the main factors involved in a general way as forces and resistances entering into soil conservation research. This is merely intended as an aid in analyzing particular problems, since before highly efficient conservation practices can be developed and applied to a problem area, the processes involved must be understood in terms of the various forces and resistances which constitute the process. An analysis of these forces and resistances will help segregate the elements of the problem and furnish leads to the types of research necessary for its solution.

OUTLINE OF FUNDAMENTAL FACTORS IN SOIL AND WATER CONSERVATION

I. Forces involved in soil erosion, sedimentation, runoff, and water use and management
- A. Precipitation
  - 1 Form
  - 2 Distribution (seasonal, annual, cyclical)
  - 3 Intensities
  - 4 Amount
  - 5 Impact characteristics (drop size, velocity)
- B. Solar radiation as affecting
  - 1 Temperature
    - (a) Air
    - (b) Soil
    - (c) Water
    - (d) Plant (governing evapotranspiration)
  - 2 Photosynthesis (rate of cover development)
- C. Gravity affecting
  - 1 Water movement
    - (a) Surface
      - (1) Sheet
      - (2) Channel
    - (b) Subsurface movement
    - (c) Fluid properties
  - 2 Ice movement
    - (a) In streams
    - (b) Mass
  - 3 Soil movement
    - (a) In mass
    - (b) In flowing water
    - (c) Deposition
- D. Molecular forces affecting
  - 1 Soil
    - (a) Swelling
    - (b) Shrinking
    - (c) Slaking
    - (d) Dispersion
    - (e) Drying
    - (f) Cementation
  - 2 Water
    - (a) Evaporation
    - (b) Capillary (pF)
  - 3 Soil solution
    - (a) Base exchange
    - (b) Leaching and flushing
- E. Wind
  - 1 Velocity and turbulence
  - 2 Direction
  - 3 Distribution and duration

II. Resistance to forces involved in soil erosion, sedimentation, runoff, and water use and management
- A. Soil
  - 1 Size of particles
    - (a) Dispersed (texture)
    - (b) Aggregated
  - 2 Structural stability
    - (a) Cohesion
  - 3 Permeability
    - (a) Surface
    - (b) Subsurface

- 4 Moisture
  - (a) Form
  - (b) Content
  - (c) Temperature

B. Cover

- 1 Snow
  - (a) Insulation
  - (b) Moisture absorption
  - (c) Flow retardation
- 2 Vegetal
  - (a) Growth characteristics
  - (b) Density
  - (c) Seasonal protection
    - (1) Time
    - (2) Season
    - (3) Residue
  - (d) Evapotranspiration

C. Watershed characteristics

- 1 Size
- 2 Shape
- 3 Slope — concave or convex, steep or flat, long or short
- 4 Aspect
- 5 Drainage pattern and density
- 6 Geology

D. Channel characteristics

- 1 Shape and area of cross section
- 2 Slope
- 3 Roughness
- 4 Erodibility of bed and bank
- 5 Alignment

It is to be understood that no project will be concerned with all of the forces and resistances listed and that for practical purposes under certain conditions some are of secondary or of small importance. It should also be understood that the items of the breakdown are themselves complex and subject to a range of variation so that this analysis should be considered merely as a general cataloguing of factors to be considered in the analysis of specific problems. In practice we are forced to determine from field studies and observation what appear to be factors of primary influence on the question at hand. These must be evaluated singly and in probable combinations, a hypothetical solution developed and experimentally tested. In this connection we need both the laboratory analysis and statistical approach, with qualitative and quantitative measurements.

From a number of years of experience in conservation research throughout the United States there appear to be two chief defects in many of our projects. First, many of them are so wholly concerned with the immediate need that we neglect getting the measurements of physical properties necessary for connecting results obtained with one soil under one set of conditions to other soils and conditions. Thus, we fail to establish an organized body of knowledge, which by definition is science. In many cases we measure general or over-all results without even finding out *what* has specifically happened in the experiment to produce such results. If we do not know what happens, the *why*, which is necessary for a real understanding, is impossible.

It is important to analyze carefully our field or plot results if we are to arrive at the *what* and the *why*. Many of the items we generally accept as simple are not simple in fact. We say infiltration and permeability are important in preventing runoff and subsequent erosion, but when we analyze them we find very complex situations and many unanswered questions. How important are soil pores and cracks, root channels, worm holes, soil aggregates, degree of compaction, rain impacts, slacking, dispersion or wetting, swelling or shrinkage, moisture content, the *pF* of various lower layers, mulches or canopy effects, plow soles, puddling by wet tillage, the "bottlenecks" produced by more dense horizons, etc. Obviously, we have to build or store up organized information a few facts at a time. Each project and experiment should contribute, and such contribution should be recorded in such a fashion and in such detail as to permit its being useful to the profession.

The second most common fault of many projects coming to my attention is the purely academic approach. The projects purport to undertake a so-called fundamental study of this, that, or the other subject, which on its face has some connection with conservation. Occasionally such projects pay off, but if the worker does not at the start have in mind something specific for which he is searching, he usually ends up with a mass of data which is more confusing than helpful. It may contribute to our general fund of information, but in general the expectancy of useful results is small. Usually such findings are impossible to carry over to practical application without additional research because of missing links.

In general, our experience to date indicates that it is important to progress in soil and water conservation that projects which are undertaken be directed at real and important field needs of the farmers and ranchers. In some cases the objective of projects may be to obtain information necessary for the development of new areas for agriculture or for the reclamation of old abandoned areas still capable of producing food or feed. The projects should be so organized that the information gathered can be used over as wide an area as possible. The basic information obtained should be such that the results will contribute to our general knowledge of soil and water behavior. We need much more specific information as to what happens in, on, and to the soil as a basis for better management, conservation and general land use.

(*Left*) Building terraces with a Caterpillar motor grader on rolling land in south Texas • (*Right*) Caterpillar diesel tractor and bulldozer building drainage ditch 34 ft wide at the top and 15 ft wide at the bottom on a farm in Maryland

Sealing Farm Ponds

By H. N. Holtan
MEMBER A.S.A.E.

ESTABLISHMENT of farm plans for complete soil and water conservation is dependent upon proper land use and adequate water supply. Farm ponds are a key factor in this program. Usually the pond is needed at a specific location according to its purpose, but as often happens the soil material, a porous or seamy rock outcrop or some other geologic condition, may make that particular site unsuited to present concepts of construction. However, many farmers build ponds at sites which are considered unsuited for pond construction simply because the need for water at that point is great enough to be worth the high risk of failure.

This procedure results in an increasing number of "dry holes", especially in the limestone areas of Virginia. The Soil Conservation Service of the U. S. Department of Agriculture and the department of agricultural engineering of the Virginia Agricultural Experiment Station undertook a program of research in 1947 to meet this problem.

Virginia extends westward from the Atlantic Ocean across the coastal plains and over the Piedmont plateau.

Coastal plains soils are mostly sands and clays, the Piedmont soils are mostly clay, and the ridges and valleys section soils are silt loams. These silt loams are often transported soils containing mixtures of sandstone, limestone and shale origin, depending upon the elevation of occurrence. Less incised waterways and frequent rock outcropping in the ridges and valleys section are hazards to pond construction which are not prevalent in the Piedmont. Frequently it is necessary to remove all of the soil above the rock in order to provide capacity in the pond and to obtain earth for the dam. Seamy or water soluble rock thus exposed soon causes leaking and often failure of the pond.

The dams at almost all of the ponds visited were designed as a core-wall type of structure. In this type of pond a site is chosen which is underlain by a layer of clay and the earth dam is constructed with a clay core wall keyed into this underlying layer. Good pond sites are plentiful in the Piedmont division but good sites for this type of pond are hard to find in the ridges and valleys section.

As already indicated, farmers are building ponds on sites which do not meet the desired specifications. Ponds on limestone soils usually seal up and hold small heads of water, but often when a big rain fills them they blow out. The blowholes disclose that the underlying limestone has dissolved, thereby forming channels (Fig. 1). Further, it is evident that the soil mantle over these channels was insufficient to support the mass of water when the pond was filled.

Fig. 1 Channels developed in limestone underlying a pondsite

Piedmont and shale areas do not have underlying soluble limestone, hence do not present as much difficulty with pond bottoms. Failures are usually in the form of leaks through the earth-fill dam. Improper core-wall construction is perhaps the largest single factor causing seepage in these areas. In many cases convenient sources of clay for the core wall cannot be found. At the insistence of the need for a pond at a precise location a number of earth-fill dams were constructed without core wall or with a core wall of materials other than clay. In some cases these were successful and in others they were not.

Engineers tried to compensate for this lack of proper core wall by using a different direction of earth-moving traffic. That is, they believed that by repeatedly dragging the earth loads up the wet side of the fill, instead of the usual end-to-end traffic across the fill, a series of laminations would be created perpendicular to the path of seepage (Fig. 2). The few ponds constructed in Virginia using these laminations have no indication of seepage through the fill. End-to-end traffic creates planes of cleavage parallel to the direction of seepage and interruptions of the work or

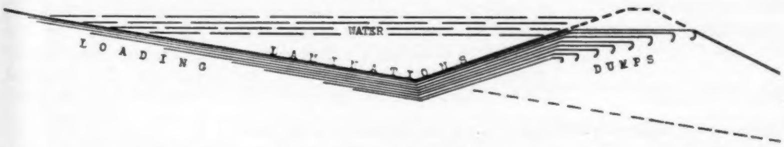

Fig. 2 Laminated pond floor created by direction of earth-moving equipment traffic. In this bag type of pond, seepage water has to pass successively through each lamination or layer separately. Compare this with the cleavage lines resulting from the usual end-to-end traffic on the fill.

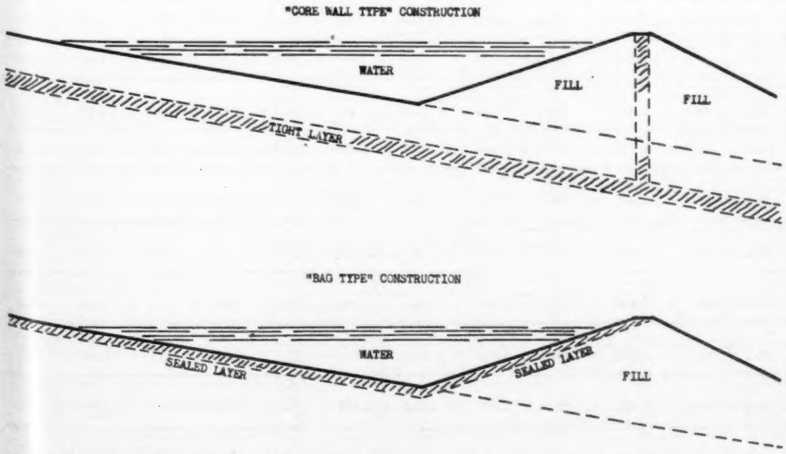

Fig. 3 Two concepts in farm pond construction: core-wall type demanding subsurface tight layer, and "bag" type wherein a sealed layer over the pond floor and up the face of the dam is created

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at East Lansing, Mich., June, 1949, on the program arranged by the Soil and Water Division. It is a joint contribution of Soil Conservation Service, U. S. Department of Agriculture, and the agricultural engineering dept., Virginia Agricultural Experiment Station.

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changes in type of material cause weaknesses along which water can seep.

In summation of the field observations it appeared that information is needed on the construction of watertight pond bottoms that are physically stable enough to support the masses of water over cavernous limestone or porous substrata, and also on the construction of core walls from materials other than clay. This led to the distinction of construction types as illustrated in Fig. 3. The core-wall type is suited to areas of unlimited soil mantle that have a definite continuous tight layer beneath the surface. The "bag" type of construction is suited for use in areas, such as limestone, where the soil mantle thickness over porous material is limited, or where no tight soil layer is found. In this type of construction a watertight layer is arranged or constructed over the surface of the pond bottom and continued up the face of the fill. The entire depth of the soil mantle is thereby used for support of the mass of water, whereas the core-wall type of construction gains no physical support from that part of the soil mantle lying above the tight layer.

Review of Literature. Most of the formal investigations reported are applicable to the core-wall type of construction.

R. R. Proctor(1)* was searching for a substitute for clay in the core wall. He found that other soils could be made water impervious by compaction, that maximum compaction could be obtained only while the soil was at optimum moisture content, and that optimum moisture content varied for different soils. He reasoned that the optimum moisture varies with the particle size. Proctor developed a technique including moisture sampling and the use of his plasticity needle(1) which provides excellent controls during constructions. Best results were obtained with other than clay soils. Clays did not remain compacted but loosened up with wetting and drying or freezing and thawing.

C. A. Hogentogler(2) did somewhat similar research for application to highway subgrade preparation. He associates the optimum moisture for compaction with the relationship of the liquid limit of the soil to the other four test constants: plastic limit, shrinkage limit, centrifuge moisture equivalent and the field moisture equivalent. He classified soils for highway construction by these various soil tests.

M. L. Nichols(3) relates compaction moisture optimum to per cent of colloids present.

B. G. Zimmerman(4) found that the optimum moisture was further affected by compaction load. Greater loads achieved maximum compaction at a lesser moisture content than did lesser loads.

Free et al(5) reported "It is evident that the dominant factors determining the compaction of soils are (a) the magnitude and nature of the compacting forces, (b) the moisture content of the soil, (c) the degree of compaction of the soil at the time the compacting forces act on it, and (d) those more stable characteristics of the soil, such as texture, organic matter, etc."

No reference was found covering effects of head of water or thickness of soil layer upon permeability after compaction. These factors together with compaction load are of primary significance in the application of the compaction principles to the bag type of pond where the entire pond floor is to be treated.

Magazines published primarily for rural circulation provide many references to individual cases of sealing a pond by some chemical treatment of the bottom. They are mostly cut-and-try methods without benefit of a well-designed and controlled study of factors involved. Applicability of these methods to other ponds is usually questionable.

Bentonites are popular as a soil sealer. As indicated by B. F. Powell, U. S. Forest Service(6), they must be carefully applied. Concentrations of bentonite due to improper mixing or too heavy an application cause weak spots in the soil which will blow out under pressure of greater heads of water. Some producers of bentonite have data sheets(7) obtainable on request which aid in the determination of the proper application of their product. They stress the importance of amount and "grade" applied, thorough mixing with soil, and the subsequent packing of the pond bottom. Blanket applications and sprinkling from a boat onto the water surface are recommended for some conditions. The grade of bentonite to be used depends upon the method of application, the depth of water anticipated, and the texture of the soil. The amount is determined by simple field tests.

"Clay bonding" is an expression which is becoming prominent. It describes a textural mixture in which sand comprises the bulk of the mass (70 per cent or more), thus giving it load-bearing capacity. A small to moderate proportion of clay (5 to 30 per cent) is used to seal, and silt is included as needed to improve the gradation of particle sizes. Seaman Motors(8) published a rather comprehensive discussion of field application of the principles of soil gradation. The Portland Cement Association(9) presents this material both in the labo-

* Numbers in parentheses refer to the appended bibliography.

TABLE A. TEXTURE, MAXIMUM DENSITY AND OPTIMUM MOISTURE OF SOME SOILS COMPACTED UNDER VARIOUS APPLIED LOADS

SOIL TYPE AND LABORATORY NUMBER	MECHANICAL ANALYSES*				COMPACTION UNDER VARIOUS LOADS AT OPTIMUM MOISTURE									
					50 lb/ sq in		100 lb/ sq in		150 lb/ sq in		200 lb/sq in		250 lb/sq in	
	Sand	Colloids	Silt	Clay	Volume weight	Optimum moisture	Volume weight	Optimum moisture	Volume weight	Optimum moisture	Volume weight	Optimum moisture	Volume weight	Optimum moisture
	per cent	per cent	per cent	per cent		per cent		per cent		per cent		per cent		per cent
Linside Loam (medium) #1	26.3	53.5	32.5	41.2	1.485	25.8	1.552	24.0	1.600	22.5	1.620	22.5	1.640	22.5
Leadvale Loam (medium) #2	20.8	54.6	36.0	43.2	1.360	30.0	1.440	27.5	1.487	26.0	1.517	25.5	1.543	25.0
Linside Fine Sandy Loam (light) #3	28.6	45.4	36.1	35.3	1.550	23.6	1.600	21.8	1.645	21.0	1.670	20.5	1.697	20.0
Linside Loam (medium) #4	44.1	33.4	30.2	25.7	1.625	20.7	1.690	19.5	1.725	19.0	1.743	19.0	1.765	19.0
Leadvale Sandy Loam (medium) #5	18.8	59.2	36.2	45.0	1.470	26.0	1.495	24.0	1.580	22.5	1.615	22.0	1.639	21.5
Philo Fine Sandy Loam (light) #6	45.3	36.2	25.1	29.6	1.650	18.5	1.730	17.5	1.760	17.5	1.790	17.5	1.790	17.5
Greendale Sandy Loam (medium) #7	18.6	51.3	48.3	33.1	1.465	25.7	1.520	24.9	1.555	24.7	1.582	24.5	1.582	24.5
Greendale Sandy Loam (light) #8	37.3	34.1	40.6	22.1	1.582	20.9	1.650	20.9	1.665	20.8	1.682	20.7	1.682	20.7
Greendale Sandy Loam (light) #9	7.5	68.9	46.9	45.6	1.410	26.9	1.470	26.5	1.498	26.2	1.518	25.9	1.535	25.8
Greendale Sandy Loam (medium) #10	15.6	59.8	38.6	45.8	1.615	18.0	1.725	17.8	1.760	17.7	1.780	17.5	1.790	17.2

* Hydrometer #12A-310288

ratory and in the field application phases. J. R. Haswell[10] found that soils of high clay content broke down to monoparticle masses under continued wetting and that they showed the most checking under wetting and drying. Sands with just enough clay to bond (9 to 10 per cent in his case) showed the least effects of continued wetting or of wetting and drying. Clay-bonded sands were also harder, as indicated by penetration of a knife-edge, than other mixtures.

Many references were scanned but only those principles, methods or materials which would fall within the economic limits of the average farm pond are included herein. Soil cement, bituminous pavings, oils, jells, etc., appear to be beyond the economic limits and facilities of the small operations concerned.

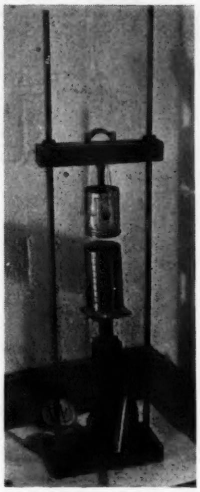

Fig. 4 Soil compaction unit

LABORATORY STUDY

Soil Compaction. Soil compaction is considered the most basic method of sealing soils found in the literature. It uses the soils without additives and achieves its result purely by manipulation. Also, it appears to be the usual recommended supplement to other methods of sealing.

Tests and controls so readily applicable to large reservoir or highway construction are considerably beyond the economics and facilities available for the construction of farm ponds. Consequently it was necessary to repeat the maximum compaction — optimum moisture work of others in order to derive some simple rule-of-thumb approximation of optimum moisture for use in the field. Also, more information is needed concerning the compaction achieved under applied loads ranging from 50 psi to about 250 psi.

The compaction unit (Fig. 4) consists of a 3⅜-in diameter automobile piston and cylinder activated by a hydraulic jack with a pressure gage tapped into its fluid chamber. Pressure or load was computed at the piston face rather than in the fluid chamber of the jack. The cylinder is closed at one end and equipped with a scale on the outside to measure depth in the cylinder. The piston is fixed in an inverted sling above the cylinder and has a rod indicator which operates outside of the cylinder upon the scale to indicate the position of the piston face, and subsequently the volume of the sample being compacted.

Five-hundred-gram samples of oven-dry soil were prepared in triplicate at an approximate starting moisture of 10 per cent dry weight. These triplicates were allowed to stand over night before being compacted. Moisture content was accurately determined by weighing the sample after placing in the compressor unit. Load was applied and volume of the sample was read, after reaching equilibrium, at each of 50, 100, 150, 200 and 250 psi compaction loads. Triplicate samples were used at this starting moisture to determine their similarity of behavior in compression. If they were truly replicates at this first moisture, they were thenceforth considered as identical and prepared at alternate moistures, usually in 3 per cent steps and compressed again. The procedure was repeated until the point of maximum compaction (optimum moisture) was well passed. Optimum moisture is used herein to indicate that moisture content at which maximum density is achieved by each compaction load.

Curves of density-moisture relationships are of the type illustrated in Fig. 5. It is evident that there is a very definite moisture for maximum compaction at a given pressure. Table A presents the mechanical analyses of each soil, the maximum volume-weight achieved by each compaction load, and the moisture at which the maximum volume-weight (density) was obtained.

Optimum moisture as well as the maximum density varies with compaction load and varies between soils. An arithmetic plotting of maximum density versus optimum moisture for a given load applied to various soils indicates a nearly perfect linear relationship. However, the mechanical analysis could not be related to density or moisture.

At a given pressure (Fig. 5), compaction is facilitated up to a certain point by lubrication due to increased thicknesses of the moisture films on the soil particles. This lubrication permits the soil particles to move together into the closest possible arrangement. Increased density reduces the pore size and increased moisture thickens the moisture films until the pressure is sufficient to overcome the surface tension and free water is extruded. This free water is slow to escape from the

TABLE B. PERCOLATION RATES OF SOME SOILS UNDER VARIOUS HEADS OF WATER AFTER COMPACTION AT OPTIMUM MOISTURE UNDER VARIOUS APPLIED LOADS

SOIL TYPE AND LABORATORY NUMBER	Soil Mantle	PERCOLATION RATE UNDER VARIOUS HEADS AFTER COMPACTION								
		50 lb/sq in Compaction load			100 lb/sq.in Compaction load			150 lb/sq in Compaction load		
		7½-ft head	15-ft head	30-ft head	7½-ft head	15-ft head	30-ft head	7½-ft head	15-ft head	30-ft head
	in	in/hr	in/hr	in/hr	in/hr	in/hr	in/hr	in/hr	in/hr	in/hr
Linside Loam (medium) from Lodi #1	6	0	0	.204	0	0	.026	0	0	0
	12	0	0	.243	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0
Leadvale Loam (medium) from Jefferson #2	6	0	.008	.072	0	0	0	0	0	0
	12	0	.012	.032	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0
Linside Fine Sandy Loam (light) from Lodi #3	6	0	.138	.682	0	.104	0	0	0	0
	12	0	0	.023	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0
Linside Loam (medium) from Lodi #4	6	0	.431	1.190	0	.060	.284	0	0	.034
	12	0	0	.214	0	0	.042	0	0	0
	24	0	0	.065	0	0	.024	0	0	0
Leadvale Sandy Loam (medium) from Berks #5	6	0	.012	.194*	0	0	0*	0	0	0
	12	0	.012	.219*	0	0	.151	0	0	0
	24	0	0	.131	0	0	0	0	0	0
Philo Fine Sandy Loam (light) from Jefferson #6	6	.097	.180	.459	0	0	.032	0	0	0
	12	0	.051	.226	0	0	.041	0	0	0.
	24	.012	.053	.182	0	0	0	0	0	0
Greendale Sandy Loam (medium) from Groseclose #7	6	.122	.473	1.092	0	.177	.398	0	.063	.257
	12	.085	.345	.966	0	.104	.322	0	.032	.177
	24	0	.024	.553	0	.036	.174	0	.015	.092
	36	0	.012	.218	0	.031	.122	0	0	0
Greendale Sandy Loam (light) from Groseclose #8	6	.201	.936	2.510	.063	.482	.946	0	.168	.3[illegible]
	12	.224	.684	1.485	.032	.461	.946	0	.114	.284
	24	.020	.287	1.033	.024	.126	.325	0	.032	.109
	36	0	.218	.412	0	.085	.170	0	0	0
Greendale Sandy Loam (light) from Groseclose #9	6	.020	.187	.379	0	.017	.204	0	0	.092
	12	.048	.142	.340	0	.015	.174	0	0	.080
	24	0	0	.068	0	0	.017	0	0	0
Greendale Sandy Loam (medium) from Groseclose #10	6	.008	.088	.573	0	0	.080	0	0	0
	12	0	.026	.141	0	0	.014	0	0	0
	24	.054	.029	.038	0	0	.005	0	0	0

* One tube only; replicate blew out under 30-ft head

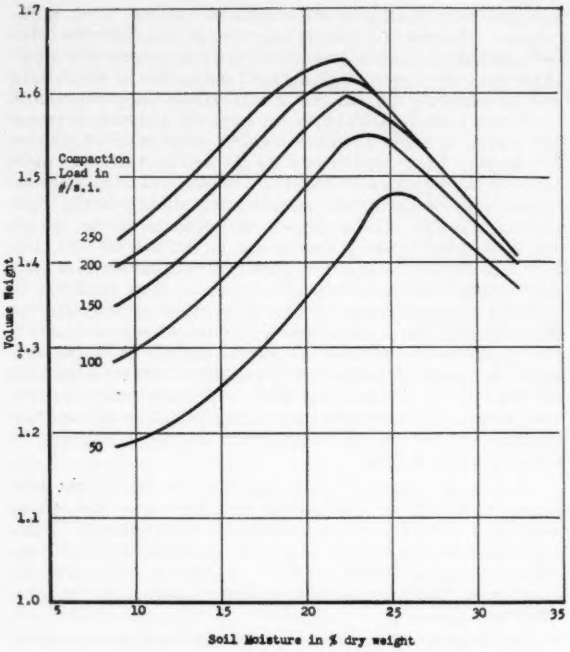

Fig. 5 Typical maximum density-optimum moisture relationship curves for various applied compaction loads

inner portions of the soil sample and hence retards further compaction. Additions of more water above this optimum results in further obstruction to compaction.

This explanation is a result of early tests wherein a filter was placed in the bottom of the compaction cylinder and an escape was provided for free water. It was found that the greatest density for a given compaction load was obtained when the sample was prepared at saturation and the compaction load was applied until water ceased to exude. As an example, if the soil in Fig. 5 were prepared at 32½ per cent moisture and compacted under 250 psi load, free water would appear shortly after application of the load. If free escape were provided for this water and the load were continually applied until no more water exuded, the resulting density would have been something greater than the present maximum of 1.64. The final moisture content would have been something less than the present 22 per cent optimum. In other words, the soil particles would have had the full benefit of the lubrication at saturation without the obstruction of free water. This early test procedure was discarded because free escape for water would not be reliable in the field, and also compaction loads could not be continuously applied over a sufficient period of time to permit this escape.

Further substantiation of the water-obstruction-to-compaction theory lies in the tendency (Fig. 5) of the curves on the wet side of optimum moisture to follow a common path regardless of compaction load. Since water cannot be compacted, the load magnitude is of no significance in this range.

For practical purposes, optimum moisture content is that amount of moisture affording the maximum lubrication of soil particles but not sufficient to obstruct compaction. It is the moisture just short of that which would exude free water under the compaction load applied. In the laboratory this was attained by saturating a sample, compacting until free water appeared (if at less than desired load), and draining over 60 cm of tension. Usually one such initial partial compaction and about 12 hr drainage permitted final compaction without appearance of free water. The 60 cm is believed comparable to field drainage tension.

Field personnel could recognize the optimum moisture condition approximately as too wet for good tilth, but not wet enough to exude free water during the compaction process.

Previous work on permeability of compacted soils is directly applicable to core-wall construction, but the bag type of pond bottom introduces several new problems in application:

1 The permeability of a compacted soil after removal of the compaction load

2 The effect of various compaction loads on permeability

3 The effect of head or depth of water on permeability

4 The thickness of soil mantle needed to seal and support various heads of water

The permeameter shown in Fig. 6 was designed and constructed to permit application of any desired head of water to a number of samples simultaneously. Head is indicated by the pressure gage and the public water system is used as a source. Early tests proved the need of a pressure stabilizer since pressures in the line varied almost constantly due to withdrawals by users in other parts of the building.

An ordinary household commode valve was converted to a single-beam weight valve (Fig. 7). By setting the water-line faucet to permit a slight excess of water over that needed to supply percolation through the samples, a continuous waste through the weight valve is arranged. Position of the weights on the beam then determines the pressure this waste has to overcome to escape. This pressure due to the weights has to be equal to or slightly greater than any drop of pressure occurring in the line from consumptive use in other parts of the building. Settings are readily made by cut and try. The faucet setting is a matter of experience; too great a waste creates turbulence in the irregular conduit through this particular unit which disrupts the smooth action otherwise obtained.

Thus controlled, the water pressure is piped to each of twelve samples through the distribution system on the top of the permeameter (Fig. 7). Each sample can be cut in or out of the system by means of individual valves.

Samples in cylinders are clamped beneath the table top to the flange, using a rubber gasket, at the end of each water line. The clamp consists of two rods, adjustable up to four-foot length of sample, with a funnel plate and crossbar as its base. Thumbscrews in the crossbars are used to move the funnel plates upward between the rods thus pressing the soil cylinder tightly against the gasket. Pails are hung on the thumbscrews to catch the percolate emerging from the funnels.

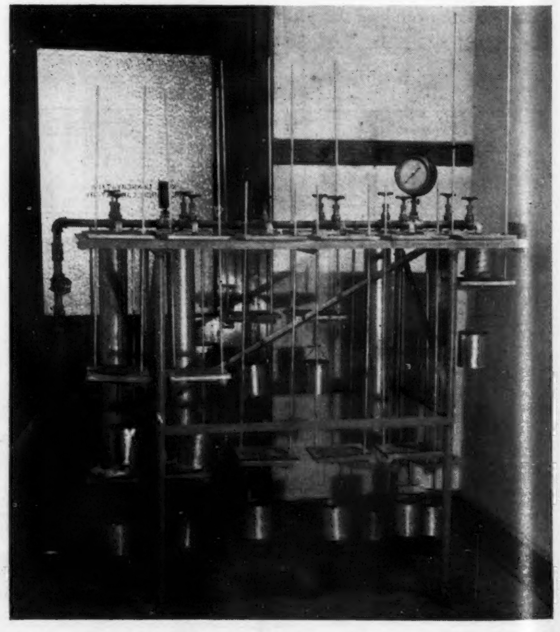

Fig. 6 The permeameter. The sample at extreme right shows the crossbar, thumbscrew and funnel plate. The funnel plate slides freely on the two rods thus clamping the sample to the gasketed plate on the table top. Holes through the table permit direct contact between the sample cylinder and the plate gasket

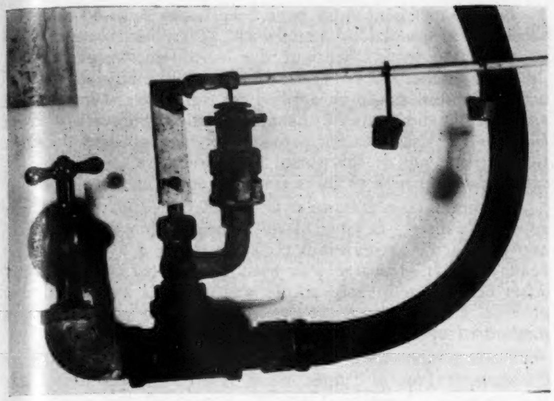

Fig. 7 Pressure stabilizer made by converting a household commode float valve to a single-beam weight valve

Open-end cylinders were constructed of 22-gage galvanized iron, 4-in diameter, with lock seams soldered and smoothed on the inside. They vary in length from 6, 12, 24, 36 to 48 in to represent equivalents of soil mantle thickness in the field. The applicability of these laboratory-packed samples to field conditions appears valid when it is considered that the soils in pond bottoms will also be manipulated soils.

The compaction unit is adaptable to use with these 4-in diameter cylinders. The piston is exchanged for one of proper size and the adjustability of the sling holding the piston is used to capacitate various length cylinders. A steel plate is used between the sample and the jack since these cylinders are open end. Toweling is folded and placed beneath the sample to prevent the moist soil from oozing out under compaction. Similarly toweling is placed ahead of the piston face to prevent oozing and also to avoid a troweled effect on the soil surface, from the smooth flat piston face, which might affect permeability of the soil sample.

Convenient pond sites in the ridges and valleys section of Virginia almost always occur on alluvial or colluvial soils. Samples of these soils were taken to represent origins from standstone, limestone, and shale. Textures range from fine sandy loams to loams. These soils are presently viewed with skepticism for pond construction. They are, however, within the textural range of soils successfully compacted by Proctor[1] for core-wall construction.

Procedure of the compaction-permeability tests constituted a search for the lowest compaction load and the least soil mantle thickness needed to render each soil impervious under various heads of water. All samples were prepared in duplicate. Testing began with a 6-in sample compacted under a 50 psi load placed under a 7½-ft head of water. If no percolate appeared at the end of an hour, the head was increased to 15 ft and subsequently, at the end of another hour, to 30 ft. These heads of water represent the usual range encountered in farm pond design.

If the sample was other than impervious under any or all of these heads, it was drained and recompacted at 100 psi and resubmitted to the three successive heads of water. The maximum load which could be dependably obtained in the field was estimated at 150 psi. Therefore, if the 6-in sample still leaked after this compaction, for any or all heads, the test was repeated using 12-in samples. The thickness of mantle was increased as needed from 6, 12, 24, 36 to 48 in. When the lowest successful combination of compaction and mantle thickness had been determined, it was tested again the following day for stability of compaction, i.e., stability of the seal.

Data from these tests are presented in Table B. Several distinct trends are of special interest in this table:

1 Percolation varies directly with head of water for each mantle thickness, compaction load, and for each soil type.

2 Percolation varies inversely with thickness of mantle.

3 Percolation varies inversely with applied compaction load.

4 There is a very significant difference in the mantle thickness and the compaction load needed to seal the various soils.

The first three observations are clearly illustrated, by using averages of all soils, in Table C and in Fig. 8.

TABLE C. AVERAGE PERCOLATION RATES OF TEN SOILS OF VARIOUS THICKNESSES AFTER COMPACTION AND UNDER VARIED HEADS OF WATER

Mantle	Compaction load			Head of water		
thickness, in	50 PSL, in/hr	100 PSL, in/hr	150 PSL, in/hr	7½ ft in/hr	15 ft in/hr	30 ft in/hr
6	0.342	0.098	0.032	0.017	0.114	0.339
12	0.184	0.077	0.023	0.013	0.067	0.204
24	0.085	0.024	0.008	0.004	0.020	0.094
36	0.029	0.014	0	0	0.012	0.031

It becomes obvious that mantle thickness, compaction load, and head of water are very definite factors to be considered and used in construction of pond bottoms.

The manipulation and extent of application of these factors have not been successfully associated with any ready soil criterion as yet. L. D. Baver[11] and others found a relationship of permeability to pore size, but this is not considered a readily discernible criterion for field use. For the present it appears advisable to include compaction, mantle and head studies as a laboratory service performed upon request from the field. Such a service is being considered at Cornell University for the vicinity of Ithaca, N. Y. At Blacksburg, Va., samples are brought in for testing in the laboratory from prospective pond sites having special research interest. As more data accumulate, periodic analyses may reveal a basis for field determinations.

Two of the samples brought in from the field represent the near extremes of soil texture, i.e., clay and sandy loam. Mechanical analyses indicate the texture of the clay to be 32.8 per cent sand or larger, 23.5 per cent silt, and 43.7 per cent clay. The sandy loam was composed of 76.9 per cent sand or larger, 13.4 per cent silt, and 9.7 per cent clay. Twelve-inch columns of soil, com-

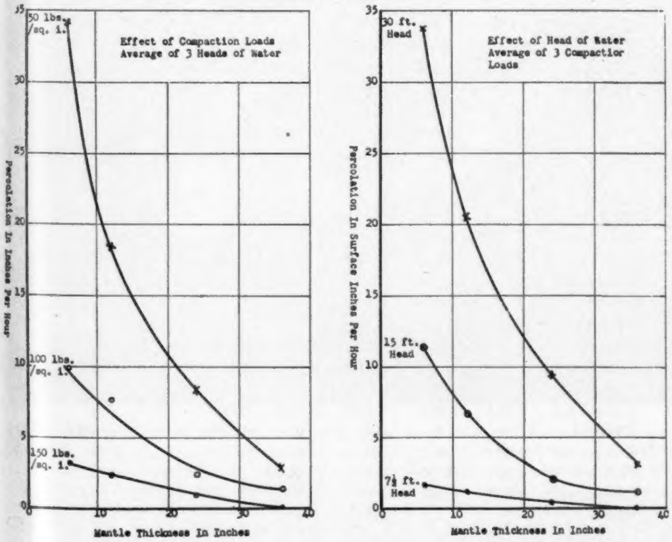

Fig. 8 Average percolation rates of ten soils of various thicknesses with head of water varied and with compaction load varied

pacted to seal against 30 ft of water, were tested repeatedly over a period of time to observe the stability of the compaction seal. Results of these tests are compared in Table D.

TABLE D. COMPARISON OF STABILITY OF COMPACTION ON A CLAY SOIL AND A SANDY LOAM

		Compaction		Percolation		
Soil no.	Soil type	Date and condition	Load, psi	Date	Head, ft	Rate in/hr
11	Clay	7/ 8/48	100	7/ 9/48	30	0
		Kept wet		7/10/48	"	0
		"		8/12/48	"	0.58
12	Sandy loam	8/29/48	150	8/30/48	30	0
		Kept wet		9/14/48	"	0
		"		10/ 1/48	"	0

The sandy loam fits very nicely within the specifications of "clay bonding" as described in the literature[8].

The 76.9 per cent sand provides the strength to support the mass of water and the silt improves the gradation of particle size needed to facilitate bonding by the clay. Clay is needed only in sufficient quantity to bond the particles of the mass together. It appears that for this combination of this particular sand and silt 9.7 per cent clay is sufficient to perform the bonding, and further that this amount of clay and silt is not excessive enough to separate the sand particles and thereby weaken the supporting capacity of the sand.

The loosening up and subsequent seepage of the clay after a month's time bears out Proctor's[1] and Haswell's[10] conclusions concerning clay soils. Excesses of clay absorb water which separates the particles thus causing a decrease in density of the soil mass. Lubrication by this water between the clay particles weakens the supporting capacity of the soil.

Dispersion of Soils. Numerous requests, suggestions and recorded instances concerning the use of chemical dispersion agents for sealing soils are on hand. Chief among the reputed dispersing agents is salt (NaC1). Investigations in the laboratory revealed no dispersion whatsoever, of the soils herein considered, by using sodium chloride. Theories and facts of soil dispersion are very thoroughly covered by Baver[11]. His discussion of the methods of removal of flocculating ions and the subsequent peptization of the colloidal particles to effect dispersion should be consulted by anyone entering this phase of soil sealing.

In the laboratory some soils were quite thoroughly dispersed by merely working them with water as a paste. Sodium hydroxide, sodium carbonate, sodium oxalate, and sodium silicate in the proper solutions were the most reliable agents for application to all of these soils. Each of these presents a problem of handling in application to the field, but they were used in the laboratory study because of their reliability.

It was found that, when chemically dispersed, these soils gave less percolate than when aggregated, but the dispersed soil could not be rendered completely impervious to greater heads by compaction as could the aggregated soil. Some mantle thicknesses compacted to seal under appreciable heads of water in the aggregated state blew out when similarly treated after being dispersed. Apparently the dispersion weakened the structural stability needed to support the weight of water. Other dispersed soils which did not blow out failed by not remaining compacted. They loosened up and yielded percolate after standing over night. According to results obtained in the laboratory, dispersion agents would reduce seepage but would not provide a complete seal. Further, they should not be used in a limited soil mantle thickness, especially under appreciable heads of water since they tend to weaken the physical stability of the soil.

Bentonites. Bentonites have been much misused and consequently misjudged by many users. They have been applied as a "magic wand" without due consideration of amount, "grade", or method of application. Just like any other product, bentonites should be applied according to the instructions and recommendations of the producers. Laboratory work at Blacksburg, Va., does not provide answers to all of the questions arising out of the use of bentonites but results do indicate the seriousness of indiscriminate applications.

Bentonite clay 200 mesh-fine was mixed dry in various amounts with a 5-in layer of soil. The sample was then wetted and compacted at optimum moisture under a 50-psi load. A head of 30 ft of water was used for all permeability tests. After being tested, each sample was removed and puddled to provide a comparison of compaction and puddling as a method of application.

Table E presents results of these tests. The soils used are the same as those of Tables A and B with the addition of clay and the sandy loam of Table D. Successful applications for these soils ranged from ½ lb per square foot of surface to as much as 1½ lb if compacted and 2 lb per sq ft if puddled. In tons per acre of pond surface, this would be equivalent to 11 tons, 33 tons and 44 tons, respectively. At present no association has been developed between amount of application and any given charactertistic of these soils.

Puddling usually requires more bentonite to seal a soil than was needed if supplemented by compaction. A very definite tendency was noted toward blowing out, as the amount of bentonite was increased beyond the optimum application. This was particularly evident in puddled soils.

SUMMARY AND CONCLUSION

1 A new concept in pond construction is needed for those areas unsuited to the core-wall type of pond. The "bag"-type construction of Fig. 2 is adapted to areas of limited soil mantle and areas wherein no reliable subsurface tight layer can be found.

2 R. R. Proctor et al have proved that soil manipulation is very effective in sealing soils to be used in the earth fill. Complete instructions for application of these principles are available[1].

3 The laboratory work herein (Continued on page 133)

TABLE E. MIXED BLANKET APPLICATION OF BENTONITE AND RESULTING PERMEABILITY UNDER A 30-FT HEAD OF WATER AT 50 psi COMPACTION LOAD

		Percolation rate after various applications of Bentonite in pounds per square foot of surface*							
Soil no.	Condition	¼ in/hr	½ in/hr	¾ in/hr	1 in/hr	1¼ in/hr	1½ in/hr	1¾ in/hr	2 in/hr
1	Compacted	0.031	0.006	0.006	0				
	Puddled	0.030	0.002	0.009	0				
2	Compacted	0.052	0.025	......	0.022	0.011	0	0	0.043
	Puddled	0.049	0.017	......	0.013	......	0.024	0	0
3	Compacted	0.037	0.079	0.020	0.019	0	0		
	Puddled	0	0	0.008	0.007	0.004	0		
4	Compacted	0	0	0.002	0.007	0	0.012		
	Puddled	0.026	0.016	0.005	0.001	0	0		
5	Compacted	0.030	0.002	0	0				
	Puddled	Blew	0.022	0.024	0				
6	Compacted	0.121	0.003	0	0.009				
	Puddled	0.004	0.004	0	0				
7	Compacted	0.192	0.127	0.013	0				
	Puddled	0.116	0.036	0.026	0.005	0.006	0.139		
8	Compacted	0.984	0.376	0.180	0.025	0.004	0	0	0
	Puddled	0	0	0	0	0	0	0	0
9	Compacted	0.665	0.096	0.376	0.408	0.007	0	0	0
	Puddled	0	0	0	0	0.010	0	0.005	0.115
10	Compacted	0.052	0	0	0				
	Puddled	0.027	0.094	0.076	0.206				
11	Compacted	0.022	0.002	0					
	Puddled	0	0	0.813	0.011	0	0		
12	Compacted	0.180	0						
	Puddled	0.140	0						

* With 3.85-in(diameter)by 5-in cylinders

Distribution of Air on a Hay Drier

By E. F. Olver and A. W. Clyde
JUNIOR MEMBER A.S.A.E. FELLOW A.S.A.E.

OF THE many unexplored phases of hay drying, the distribution of air is probably the number one problem today. One of the reasons why little research has been done on this phase is that the methods of measuring the velocity of the air leaving the drier have been inadequate. H. D. Bruhn, in an article in AGRICULTURAL ENGINEERING, (April, 1946), said "With available instruments it is only possible indirectly to determine air velocity and direction in a mow of hay." Several methods of measuring the air velocity are compared in this study.

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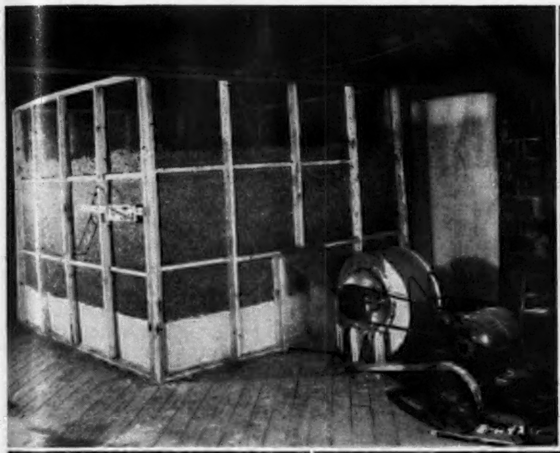
In Pennsylvania most of the barns are divided into narrow high haymows, the average size being 20 ft wide, 40 ft long, and 16 ft in height. In some other sections of the country much wider and lower mows are common and a much more elaborate duct system is required. With the narrow mow the duct work usually consists of a single, high, main duct in the center of the mow. Therefore, much of the information in this article is based on a model hay drier with a single duct.

In cross section the model in Fig. 1 was made half the size of the average Pennsylvania mow. Dry timothy hay, chopped to a theoretical length of ¾ in, was put on the drier and packed thoroughly. The backward curved fan was used with a variable-speed drive, powered by a 3-hp motor. An inclined manometer was used for measuring static pressures.

The first device used to measure air velocity was the smok-



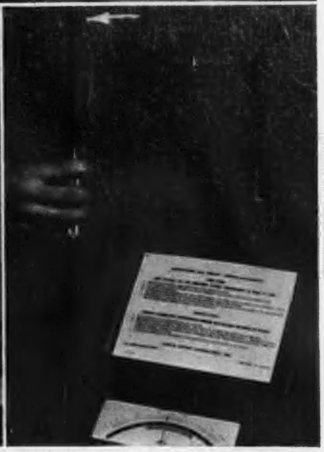


Fig. 1 (*Upper left*) Model hay drier, 10 ft wide, 10 ft long, and 8 ft high. Two main ducts were used: one 3 ft high, 2 ft wide, the other 7 ft high and 2 ft wide. The end of the duct was 2.5 ft from the end of the mow, and it was airtight for 2.5 ft next to the fan • Fig. 2 (*Upper right*) Smoking apparatus. Air was blown into two bottles, one containing HC1 and the other household ammonia. The fumes from these two bottles traveled through two rubber tubes connected to two metal tubes, which were put into the hay side by side. When the fumes combined in the hay, a white smoke was formed • Fig. 3 (*Lower left*) A velometer records the velocity of a small area. To obtain the average velocity of a larger area, many readings must be taken. The air moves straight through the meter and moves a vane which registers the reading • Fig. 4 (*Lower center*) Anemometer and funnel which did not prove very successful for measuring low-velocity air on a hay drier • Fig. 5 (*Lower right*) Hot-wire meter employs the principle of the heated thermocouple and consists of a direct-reading meter and an air velocity sensitive probe attached by a flexible cable. The sensitive part is at the end indicated by the arrow.

ing apparatus, Fig. 2. The operator blew the smoke into the hay. The air from the fan, moving through the hay, blew the smoke through the plastic cylinder where it was timed for a distance of 3 ft. The cylinder was 4 ft long and 12 in in diameter.

The following difficulties were encountered with the use of the smoke apparatus:

1 Any room drafts caused "chimney effects" and varied the readings tremendously.

2 Since air does not flow evenly from the hay, smoke entered the cylinder at various rates at different points and confused the operator.

3 It was very difficult to follow the first tip of smoke, for many times it would disappear before the end of the cylinder.

4 The smoker could not be used on high velocities because of the inaccuracy in correctly timing the smoke. Excessively low velocities were next to impossible to time because the smoke became turbulent before it reached the end of the cylinder. Probably the easiest velocities to record were between 15 and 30 fpm.

5 It was impossible to use the smoker near the fan because the smoke was pulled from the cylinder by the fan.

In general, this method of determining air velocity took a long time and gave a wide variation in readings.

The second instrument used for air velocity measurement was the velometer, shown in Fig. 3. It was the easiest instrument to use, but was not accurate below 20 fpm. The readings are read directly in feet per minute, and the instrument can be used for velocities as high as 2500 fpm.

The third instrument employed for air velocity measurement was the anemometer which measures feet of air passing through it and is timed to obtain feet per minute (Fig. 4). This instrument was practically worthless for the measurement of air as it leaves the hay, for these velocities are seldom great enough to move the propeller in the anemometer. Velocities much below 50 fpm did not operate the anemometer to record a reading.

A funnel was also used in an attempt to increase the readings of the anemometer to a point where the anemometer would register a reading, regardless of how small the amount of the air issuing from the hay. The funnel helped somewhat, but the combination was still inadequate for this work. The subject of funnels will be discussed later in this report.

The last method tried for air measurement was the hot-wire meter or thermoanemometer as shown in Fig. 5. The hot wire is located in the small opening near the tip of the probe. It measures the air velocity feet per minute at a very small point. A different reading could be obtained from almost any spot. It was next to impossible to produce a constant average; therefore, the use of this instrument alone was not feasible.

Since this meter could not satisfactorily be used alone, three different funnels were used with it. On one funnel the large end had twice the area of the small end. Another funnel had the large end ten times larger, and on the third the large end was five times the area of the small end. The latter gave the best results.

A funnel has the effect (usually desirable) of averaging spots of high and low air flow. It also has the undesirable effect of setting up resistance and of causing some air to bypass the funnel and not be measured. For this reason a funnel with an area ratio of 5 to 1 does not give a reading five times as great as the velocity at the hay surface. The air in the funnel is accelerated and a rise in static pressure near the hay surface is required to cause the acceleration. This may be expressed as an energy loss, $\frac{1}{2}mv^2$. As the velocity increases, the energy needed to give acceleration in the funnel increases as the square of the velocity. For this reason, it is to be expected that more air is lost around the edge of the funnel at high velocities than at low. Previous experiments with a known air flow had shown definitely that a funnel causes bypassing, and that the amount of by-passing is quite variable. A fixed proportion, therefore, does not exist between the funnel readings and the true velocity. In spite of this, the funnel is believed to be valuable.

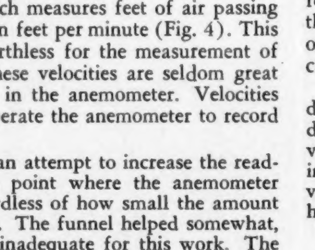


Fig. 6 Sheet metal funnel used with the hot-wire meter

A funnel was needed that would give a reading on the accurate range of the instrument scale for the lowest speeds of air flowing from the hay. The smallest funnel, mentioned above, did not raise the lowest air speeds from the drier sufficiently to be read on the meter. The largest funnel increased the readings more than necessary, which probably meant there was a greater proportional variation in the low and high readings when using the largest funnel than when using the other two. Fig. 6 shows the dimensions of the funnel which gave the best results for all-around usage. In other words, when using the hot-wire meter and this funnel, readings could be taken all over the drier to give a relative comparison of the speeds of air issuing from the drier at any point. In fact, these two instruments were the only ones that could be used to obtain readings at every point on the drier.

Two of the tests run on the model hay drier using the hot-wire meter and funnel are given in Fig. 7. The numbers on the diagrams are relative figures for air speed. Test 5 shows the distribution of air using the 2 x 3-ft high duct, and test 6 shows the same for a duct 2 x 7 ft high.

These diagrams show the top, rear, front, and left side views of the drier connected for ease in showing the readings. If the top were folded down 90 deg and the front and rear folded in 90 deg, the sides would be in the same position as on the drier. The left side is considered left as one faces the front of the drier. No readings were recorded for the right side because they were so similar to those on the left side.

In comparing the two tests one can easily see how the air distribution has been improved by the use of the high narrow duct in test 6. On the left side in this test the air speed was very even except next to the floor in the middle. The left side in test 5 is much different. Near the top of the left side the velocities are nearly zero, while next to the floor they are much higher than in test 6.

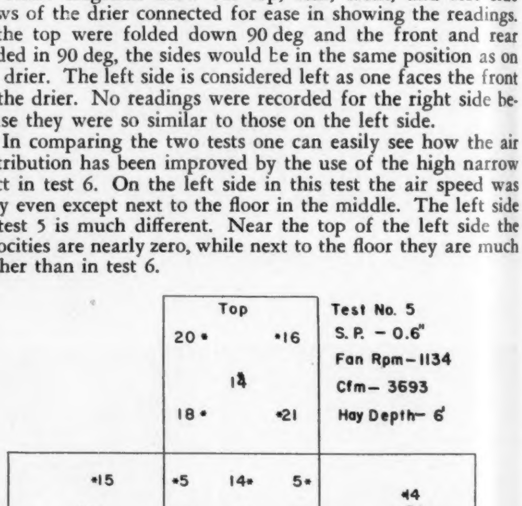


Fig. 7 Tests made using hot-wire meter with 5-to-1 funnel

For a height of 1.5 ft from the floor the wire hardware cloth was plastered to prevent air loss next to the floor. First tests without any plaster on the walls near the floor had shown very high velocities next to the smooth floor surface. When the plaster was added, it helped considerably.

From these tests it is readily seen that the area of the duct exposed to the hay must have much to do with air distribution. The higher the duct became, the more even the air speeds became on the left side in the two tests conducted. In test 6 the duct was closer to the top of the hay than in test 5. There was more total duct area in test 6, and there was more duct area near the top of the mow in this test. All of this leads to more even air distribution throughout the mow.

There are several other things of note that can be brought out in these two tests. The air output was approximately the same in both, but with a much larger duct the pressure dropped to 0.225 in as compared with 0.6 in in the smaller duct. In test 6 the speed of the fan could be lessened, also. This means that less horsepower is needed for the same air output using a larger duct.

Several other types of tests were conducted with the use of the various instruments to measure the air leaving the drier. In several of the tests the indications were that the distance from the end of the duct to the end of the mow and the airtight area of the duct next to the fan (2.5 ft in these tests) should be less than the distance from the side of the duct to the side of the mow (4 ft on the model). The limiting factor was the air penetrating the corners. With these distances in these tests there was an extra loss out of the rear of the drier and around the fan, but this was necessary in order to give adequate air supply to the corners. Using either duct, the results were the same. Had the distances been greater than 2.5 ft, the corners probably would have been starved for air.

In another test making the bottom of the duct airtight for a distance of 1.5 ft above the floor did improve the distribution of air throughout the drier. It gave less loss near the floor and increased the output of air out the top of the drier.

In still another test the hot-wire meter was tied to the left side of the drier at various points and the speed of the fan was varied from high to low speeds at each point. These records showed that in proportion the greatest increase of air speed was at the points where originally velocities had been low. We can, therefore, say that when the output of the fan was increased, there was a greater increase in proportion from the top of the drier where low velocities had been than at the bottom where high velocities occurred. This gives an indication that it is possible to oversize a hay drying fan, in an attempt to get more air through the top of the hay.

Air Distribution in Mow Driers on Farms. During the summer of 1949, seven farm drier installations were studied regarding air distribution to find out if the model drier results resemble those of actual driers. In most cases a drier has only part of one side and the top open so that air measurements can be made. This definitely limits the information that can be obtained from the regular drier, concerning air distribution.

There are many things that cause hay drying results to vary, such as loose fan belts, hay too green or wet, hay packed excessively where the hay fork dropped the hay on the drier, filling mow half full at first and completely filling after first hay was nearly dry, varying hay maturity, filling drier to varying depths, recirculation of air, etc.

On one drier the hay was 24 ft deep. In order that the air penetrate this depth of hay, a secondary duct was placed a few feet above the original duct and fed by a vertical flue through the middle of the two ducts. The resulting air resistance was very low, giving a pressure of 0.18 in. In other words, there was so much duct area that only a low pressure was needed. This system seemed very satisfactory for air distribution, except that there was one point on the top that had excessive air loss. This was entirely due to poor management when the hay was placed on the drier.

One example in the field of not having enough duct area near the top of the mow was shown in a particular mow 20 x 45 ft with a duct 4.5 ft x 6.5 ft high. The hay was put on 14 ft deep and very green, and at no point on the top of the drier was there a reading greater than 9, using the hot-wire and funnel. On the side of the mow 6 ft off the floor the readings averaged 63. Even though there was approximately the same amount of hay above the duct as at the side of the duct, there was excessive side loss since more duct area fed the side of the mow than the top of the mow. Even though this drier, because of the exceptionally green hay, showed this indication drastically, all of the other driers had the same indications because the side losses were much greater than that at the top of the mow.

Ways of putting more air to the top of the mow are by higher ducts, secondary ducts, or vertical flues. Many times the heights of mows are so great that a very high duct would be impractical. Probably one of the latter two methods would suit the situation better.

CONCLUSIONS

1 No one instrument was found practical to measure exactly the velocity of the air leaving the hay from every point on a drier.

2 More factors influence the accuracy of the smoker than any of the other instruments. It is much too slow and inaccurate for a close check on air measurements, especially at very high and very low readings.

3 The velometer is easy to use in measuring air velocity. It is not accurate at low velocities which are common on hay driers.

4 The anemometer, when used alone, is of no practical value in measuring low air velocities.

5 The hot-wire meter when used alone was not practical for measuring air velocities on hay driers, but when used with the funnel having an end area ratio of 1 to 5, it proved more satisfactory than any of the other instruments tried.

6 When a funnel is used to aid in taking air measurements, it can give only relative results, and no exact proportion was found between the true velocity and the funnel readings.

7 Regardless of the instrument used, drafts affected the readings.

8 The trend in duct design for high narrow mows should be toward greater duct area near the top of the drier and higher ducts to get better air penetration to the top of the hay. Most of the actual farm hay driers had excessive side losses.

9 There was less resistance to the air horizontally out the sides of the mow than there was vertically out of the top due to greater duct area exposed at the sides.

10 The larger the duct area, the lower the resulting pressures, and the greater will be the fan delivery.

11 Air followed the smooth surface of the floor more readily than it went through the hay.

12 Making the outside of the drier and the side of the duct air tight near the floor decreased the air losses near the floor and increased the air output through the hay at the top of the drier.

13 Increasing the fan output increases the velocities more in proportion at the top of the drier where low velocities exist than near the floor where higher velocities exist.

Sealing Farm Ponds

(Continued from page 130)

reported indicates the applicability of soil manipulation principles to sealing pond bottoms. Factors for consideration by the field engineer are:

(a) Percolation varies directly with head of water

(b) Percolation varies inversely with compaction load

(c) Percolation varies inversely with depth of soil mantle

(d) Greater heads of water need greater thicknesses of soil mantle to provide physical support

(e) Maximum compaction can be obtained only while the soil is at optimum moisture. Optimum moisture is that condition of the soil too wet for good tilth but not wet enough to exude water during the compaction process

(f) Soils approaching the limits of "clay bonding" are best suited for sealing by compaction. Textural composition for clay bonding is roughly 70 per cent or more of sand, 30

per cent or less of clay, with silt as needed to provide good gradation of particle size.

4 Although chemical dispersion reduced the percolation rate of uncompacted soils, it did not completely seal the soils studied. It appeared to weaken the supporting capacity of the soil mantle to the extent that appreciable heads of water blew holes through the sample. Dispersed soils could not be permanently compacted in the laboratory but loosened up overnight and leaked again. Dispersion could be used in areas of unlimited soil mantle where a relatively small amount of seepage is permissible, but it would seem unwise to apply it to limited soil mantles especially over soluble limestone where even small amounts of seepage would eventually cause failure. Assuming that conditions are suited to the use of chemical dispersing agents, it would be well to perform observation tests with small amounts of soil in a glass jar to determine the effectiveness of the chemical considered in dispersing any particular soil. Also the desired concentration of the agent can be estimated from observing these results.

5 Bentonites should not be applied without a thorough investigation of conditions. Amount, "grade" (mesh) and method of application are very important to the success of its use. Tests should be performed and the producer of that bentonite should be consulted before application.

6 As the depth of the average farm pond progresses from the old foot-and-a-half-deep watering hole to the modern 8 to 15 ft reservoir, the problem of sealing is enhanced by one of physical support for greater masses of water. The engineer can no longer ignore the capacities of the pond bottom soils as structural materials.

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A Drill for Experimental Plots

By L. W. Hurlbut, F. J. Bell, and A. F. Dreier

A TRACTOR-MOUNTED four-row drill for nursery plots has been constructed and used during the past year for seeding crops in the outstate testing program of the Nebraska Agricultural Experiment Station. It is an adaptation of the machine described by Grafius*. The mechanism has been mounted on a four-wheel tractor and a variable-speed feed belt drive has been added. The development of this machine was a cooperative project between the departments of agronomy and agricultural engineering at the Nebraska Station.

The seeding unit consists of a special troughed rubber V-belt hopper which delivers the seed to a four-way divider. The measured quantity of seed for each plot is dropped onto the V belt from a shallow overhead pan approximately the same length as the hopper.

Seed coming from the V belt is dropped onto a series of baffles which cause it to spread laterally. Below the lower baffle plate the seed stream is separated into four parts by a centrally located vertical divider plate set between two adjustable plates. The divider unit is adjustable with respect to the hopper so that it can be kept level at all times.

The frame, furrow-opener equipment, gage wheels, and markers were made from standard, but somewhat remodeled, drill and planter parts.

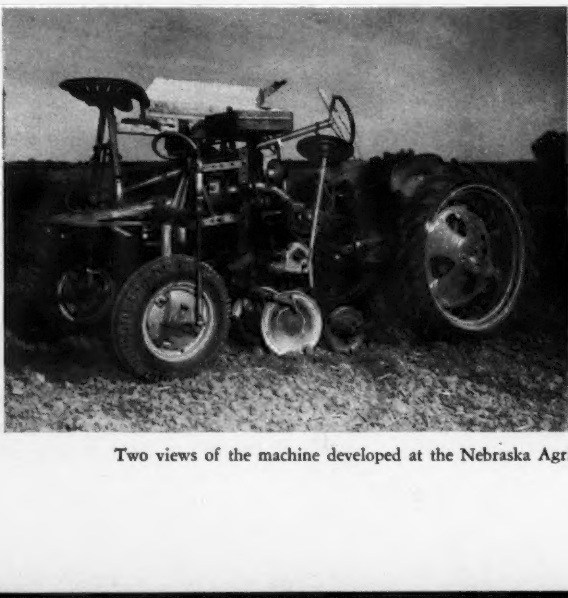
The drive originates from one front wheel of the tractor by means of a "universal" gear drive to a flexible cable. The flexible cable in turn drives a standard V belt operating on variable-pitch pulleys. This arrangement provides an adjustable drive and permits the operator to vary the linear travel of the hopper belt to fit the length of plot desired between the limits of 15 and 40 ft.

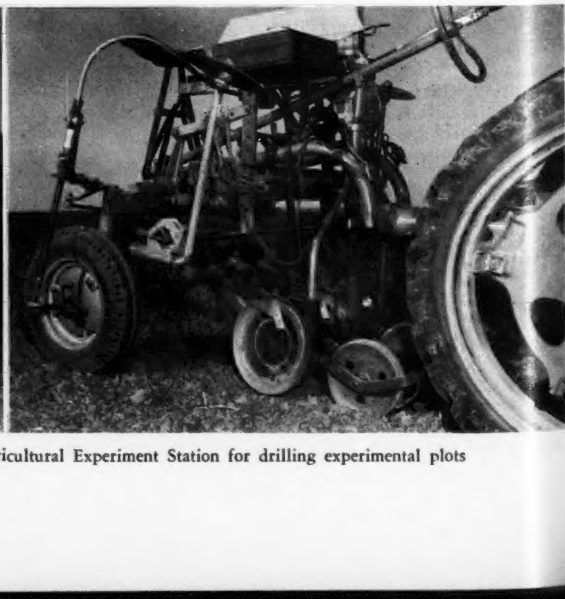
This paper was prepared expressly for AGRICULTURAL ENGINEERING.

The authors: L. W. HURLBUT, F. J. BELL, and A. F. DREIER are agricultural engineers, Nebraska Agricultural Experiment Station, Lincoln.

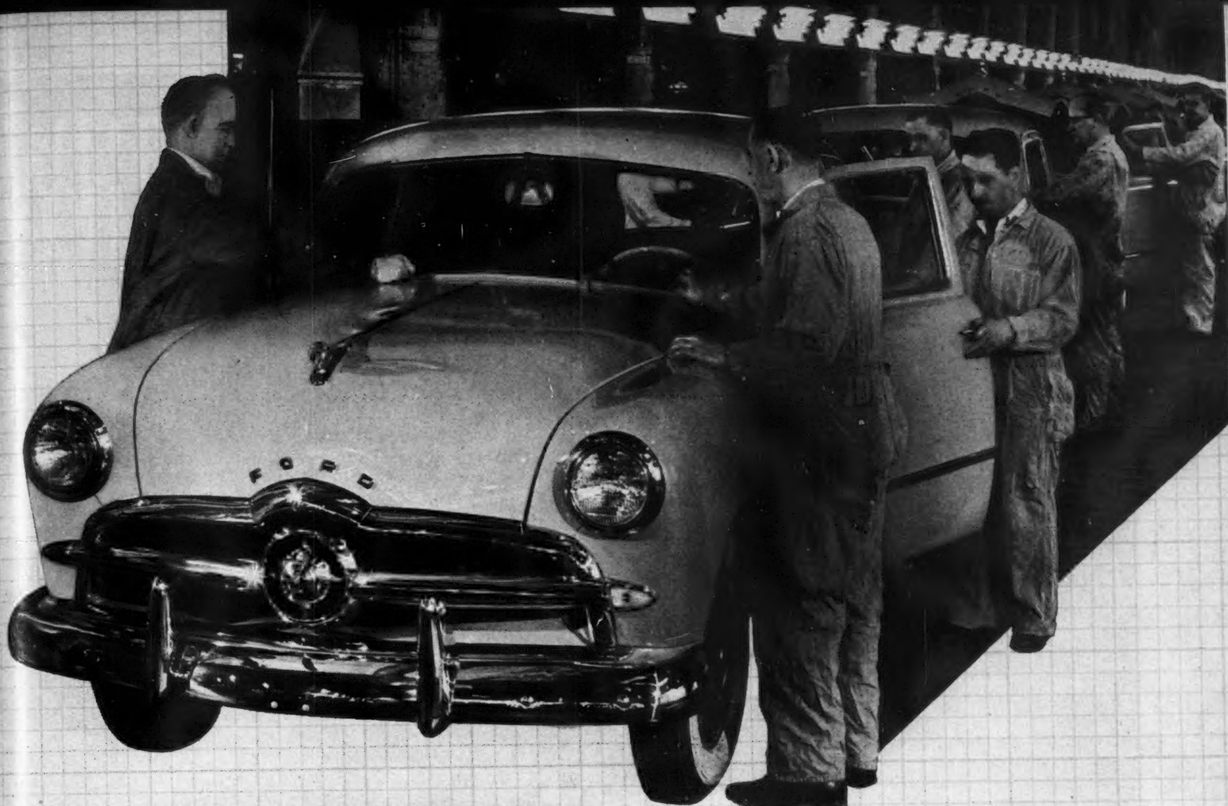
AUTHOR'S NOTE: The development of machines of the kind described in this article affords a wonderful opportunity for good co-operative work between agricultural engineering and other departments of the state agricultural experiment stations. The machine described has worked exceptionally well in the field and our station agronomists are very much pleased with it. We have cooperated with the agronomy department in providing a sprayer suitable for use on experimental plots, and also a fertilizing machine for use in planting corn in the outstate agronomy testing program. There may be a number of such devices developed at various experiment stations which would be of interest to agricultural engineers in general. If this is the case, we would like to see some effort made to publish in AGRICULTURAL ENGINEERING brief descriptions of such machines.

* GRAFIUS, J. E.: A Four-Row Nursery Seeder. *Jour-Amer. Soc. Agron,* 41:267-269 (1949).





Two views of the machine developed at the Nebraska Agricultural Experiment Station for drilling experimental plots


FORD

Soil Erosion Controllers for Gated Irrigation Pipe

By R. T. Tribble
JUNIOR MEMBER A.S.A.E.

SOIL erosion is present in many areas where a high rate of flow is necessary for efficient distribution of irrigation water. The installation of gated irrigation pipe, for experimental layouts, has resulted in considerable damage from soil erosion as illustrated in Fig. 1. The presence of soil erosion, however, is not a valid reason for discarding gated pipe as a means of distributing irrigation water to the furrow.

Gated pipe has many advantages as a method of distributing irrigation water. A low rate of depreciation, portability, and positive control are more important. There are two chief disadvantages: the initial cost is high, and steep slopes introduce high operating heads and consequently create soil erosion problems.

This latter problem has been solved partially by the use of an energy dissipater or erosion controller. The device is made of 24-gage galvanized sheet metal shaped to baffle the jet, thus reducing the velocity of discharge before the water enters the furrow. The device is independent of the pipe line, simple to construct, and inexpensive.

A comparison between the erosion present with and without the controller is shown in Figs. 1 and 2, respectively, where the operating head is 10 ft and the rate of discharge is 0.02 cfs. After 4 hr continuous operation, 4000 cu in of soil were moved by uncontrolled discharge compared to 15 cu in using the erosion controller.

The problems encountered in building an erosion controller for gated pipe vary according to the arrangement of the gates, rate of flow, and the erodibility of the soil. Where gates are installed for irrigating a furrow on each side of the pipe line, a device similar to that in Fig. 3 may be used. The discharge velocity must be reduced to prevent erosion, and at the same time the required volume of water must be delivered to the furrow. Should the controller fail to catch and deliver all the water away from the pipe line, the soil beneath the pipe, which separates the furrows, is washed away and the water runs under the pipe, eventually all flowing to one furrow. Briefly, water leaving the controller must be directed away from the pipe line at a low velocity. Where it is desirable to deliver water to a single furrow, one side of the controller may be replaced by a flat piece of material curved to clamp around the pipe and seal the gate on that side.

Performance Data for the Erosion Controller. The primary factors governing the capacity of an erosion controller are the pressure head applied at the gate, gate opening, and the position of the device under operating conditions. The gate opening and pressure head determine the rate of discharge from the pipe line, while the capacity of the controller is determined by its size and operating position. Water entering the device at high velocity decreases its capacity from the standpoint of erosion control. A discharge of 46 gpm under 1 ft head through a 2 9/16-in gate opening does not cause excessive soil erosion, while a high degree of erosion is present using a 5/16-in gate opening under 45 ft of head with a rate of discharge of 26 gpm Fig. 4.

The apparatus used for collecting the information shown in Fig. 4 consisted of a test section of portable gated pipe provided with a 1¾-in connection direct to the university fire main. The pressure applied to the test pipe was varied by adjusting the gate valve in the fire main and was measured by a mercury manometer. The gate in the portable pipe was measured with calipers, while the discharge from the gate was measured by the amount of water collected in a container per unit of time. The method of measuring volume was considered sufficiently accurate for a test of this nature.

The variation in rate of discharge for a given pressure head (considering an increase from 5/16 to ⅝ in in gate opening) may be explained by the shape of the gate opening and a change in the coefficient of discharge (Fig. 5). The coefficient of discharge decreased from 0.75 to 0.68 with an increase in pressure head from 0.5 to 8.3 psi (Table 1).

TABLE 1. Variation in the Coefficient of Discharge Using ⅝-In Gate Opening

Head, psi	Measured discharge, gpm	Calculated discharge, gpm	Coefficient of discharge
0.49	12.1	16.2	0.75
1.46	20.7	28.1	0.74
3.9	33.0	46.0	0.72
5.8	39.0	56.0	0.69
8.3	45.0	66.0	0.68

The area shown between curves E and F (Fig. 4) represents the range through which a controller is needed and performs satisfactorily from the standpoint of soil erosion control. For pressure heads and rates of discharge below curve F, an erosion controller is unnecessary. Above curve E the size controller described is not adequate to prevent serious erosion. The exact location of curve E or F depends upon the erodibility of the soil being irrigated. The upper range or limit for satisfactory erosion control is especially difficult to locate; however, it is believed that curve E represents an average, considering a medium weight soil and a 3 x 3 x 12-in controller.

This paper was prepared expressly for AGRICULTURAL ENGINEERING, and is published with the approval of the director of the University of Hawaii Agricultural Experiment Station as Technical Paper 189.

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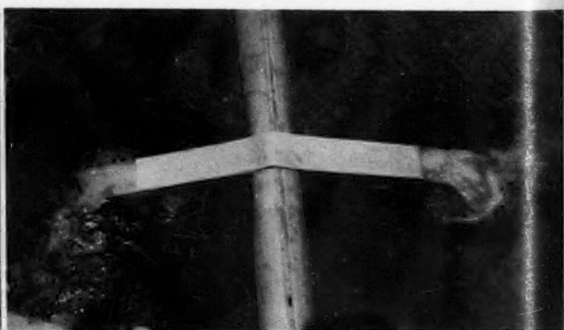


Fig. 1 (*Left*) Operation of gated pipe under 10 ft of head. The gate is adjusted to deliver about 0.02 cfs • Fig. 2 (*Right*) Top view of erosion controller operating under 10 ft of head and delivering 0.02 cfs. Erosion is negligible after 4 hr of operation

Rate of Application to Furrows. There are a number of factors to consider in determining the proper rate of application to furrows. The soil type, crop, length of furrow, and method of irrigation are most important.

In the process of developing the erosion controller, it was desirable to determine the usual rate of application used on Hawaiian soils. A survey was conducted in the vegetable and cane-growing areas, the results of which are shown in Table 2. All the areas were irrigated by small open supply ditches except the sugar cane fields where concrete flume was predominant.

The maximum rate of application was found in a papaya orchard where 55 gpm was admitted to a single open furrow. The trees were spaced 10 by 12 ft in rows 400 ft in length and were irrigated by an open ditch supplying water to shallow, 4-ft-wide, open furrows on the upper side of the tree rows. There was evidence of considerable damage due to soil erosion.

The next highest rate of application was found in the first irrigation of a ratoon planting of sugar cane, where 42.8 gpm were applied to each 400 ft furrow by means of a concrete flume. The first irrigation of a ratoon crop is considered very rapid.

The average rate of application, disregarding soil types, length of row, crops, etc., was 19.9 gpm per furrow. The average rate of application to sugar cane was 18 gpm per furrow compared to 16.5 gpm per furrow for vegetable crops. The average rate of application to the one papaya orchard studied was 46.9 gpm to each 400-ft row. The rates of application presented above check fairly close to preliminary work performed by the U. S. Soil Conservation Service.

The erosion controller operates exceedingly well at a discharge rate of 15 to 20 gpm under 35 to 40 ft of head. A higher rate of application up to 45 gpm may be used under low heads, but still greater rates of flow result in serious soil erosion regardless of the manner in which it is introduced into the furrow.

SUMMARY

1 It is believed that soil erosion controller (3 x 3 x12 in) will operate efficiently under the present rates of water application to furrows in sugar cane or vegetable crops.

2 The maximum rate of application for most crops about 17.5 gpm per 200 ft of furrow. The rate may be i creased with longer furrows, but should be decreased wi shorter furrows.

3 The range in which the controller is needed and effective varies from 5 to 45 ft of head and 12 to 46 gp (Fig. 4, curves E and F).

4 Further information is desirable for fixing the upp range of operation on various soil types.

TABLE 2. Rate of Water Application per Furrow for Various Cro

Crop	Row length, ft		Rate of flo gpm
Sugar cane	100		4.1
(first irrigation of	150		10.2
ratoon crop)	200		10.2
	225		14.1
	425		25.3
		Average	12.8
Sweet potatoes	60		10.2
	30		18.5
		Average	14.4
Corn	300		13.1
	175		17.6
		Average	15.4
Cabbage	200		14.1
	125		17.5
	150		17.5
		Average	16.4
Watermelons	200		17.5
Forage cane	350		18.5
	400		19.9
		Average	19.2
Sugar cane	250		10.2
(later irrigations)	300		14.1
	350		17.5
	400		29.9
	400		42.8
		Average	22.9
Papaya	400		38.8
	400		55
		Average	46.9

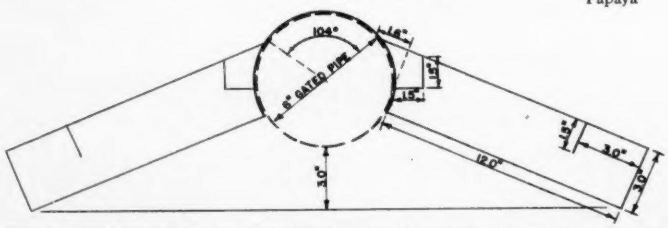
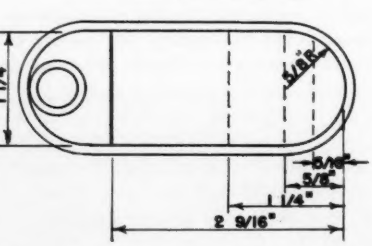


Fig. 3 End view of erosion controller showing dimensions, details of construction, and operating position



GATE OPENING INCHES	AREA OF GATE SQ. IN.	RATIO OF INCREASE IN AREA
5/16	0.239	1:1
5/8	0.612	2.56:1
1 1/4	1.423	5.98:1
2 9/16	3.034	12.68:1

Fig. 5 Details of gate used in gated irrigation pipe and the variation of gate area with respect to distance opened

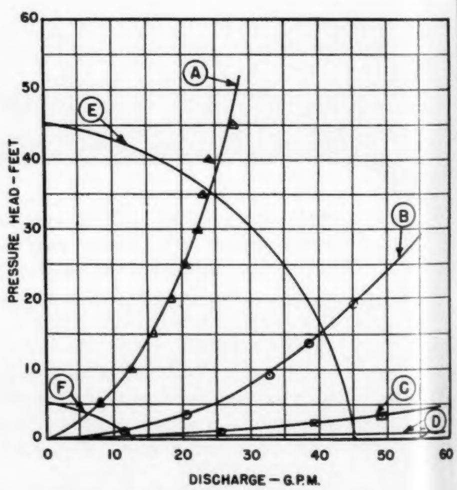


Fig. 4 Performance of an erosion controller under various pressure heads and gate openings

NEWS SECTION

Jones New Chairman Southeast Section

THOMAS N. JONES head of the agriculture engineering department, Mississippi Agricultural Experiment Station, was elected the new chairman of the Southeast Section of the American Society of Agricultural Engineers at the yearly meeting of the Section held at Biloxi, Miss., February 9 to 11. He succeeds Harry Dearing, agricultural engineer, Tennessee Coal, Iron and Railroad Co. During the past year Mr. Jones has served as secretary of the Section.

Other Section officers elected at the meeting include First vice-chairman, Fred A. Kummer, head, agricultural engineering department, Alabama Polytechnic Institute; second vice-chairman, G. D. Kite, extension agricultural engineer, Virginia Polytechnic Institute; secretary, M. T. Geddings, agricultural engineer, Duke Power Co.

The meeting just held, from the standpoint of attendance and quality of program, was probably the best meeting ever sponsored by the Southeast Section.

Southwest Section Plans Meeting

PROGRAMS on soil and water, rural electrification and teaching methods, crop processing and buildings, and power and machinery are planned for the two-day meeting of the Southwest Section of the American Society of Agricultural Engineers at Louisiana State University, Baton Rouge, April 14 and 15.

The meeting will be a feature of the dedication of a new agricultural engineering building at the University. In addition to the technical program there will be an opening address by Dr. Harold W. Stoke, president, Louisiana State University, a free barbecue at the Agricultural Center, a banquet with Dr. I. P. Trotter, dean of the graduate school, delivering the principal address, and a business meeting of the Section.

Subjects tentatively scheduled for two soil and water sessions include drainage of sugar cane land, new developments in mowing and ditching machinery, equipment operation for soil and water conservation, earth moving for agricultural engineers, the agricultural engineer's place in farm irrigation, flood protection for creeks, and heavy machinery for land clearing.

A session on rural electrification and teaching methods is scheduled to cover accomplishments and problems of rural electrification in Louisiana, rural electrification in Texas, professional agricultural engineering courses in farm machinery, agricultural engineering courses for vocational education students, and a progress report on the coordinated program for vocational education work in agricultural engineering.

Treatment of crop processing and buildings is to cover recent developments in crop drying and storage in Texas, the application of dielectric heating to crop processing, state and maturity for harvesting rice by combine, a progress report on rice storage in Louisiana, better use of lumber in farm buildings, use of steel in farm buildings, and the Housing Act of 1949.

In the power and machinery program a symposium on cotton mechanization is to cover cotton harvesting in Oklahoma, weed control in cotton, cotton mechanization in Texas, and cotton gin engineering. Other subjects to be covered include machinery for applying anhydrous ammonia, use of liquified petroleum products on farm tractors, mechanizing the industrial sweet potato, and machinery maintenance.

A.S.A.E. Meetings Calendar

March 17 and 18 — PACIFIC COAST SECTION, Logan and Salt Lake City, Utah

April 7 and 8 — MID-CENTRAL SECTION, University of Nebraska, Lincoln

April 14 and 15 — SOUTHWEST SECTION, Louisiana State University, Baton Rouge

April 21 and 22 — VIRGINIA SECTION, Hotel Roanoke, Roanoke, Va.

June 19-21 — ANNUAL MEETING, Hotel Statler, Washington, D. C.

OCTOBER 19 and 20 — PACIFIC NORTHWEST SECTION, Yakima, Wash.

December 18-20 — WINTER MEETING, The Stevens, Chicago, Ill.

Washington Section Hears Dr. Bennett

THE February 10th meeting of the Washington (D.C.) Section of the American Society of Agricultural Engineers was attended by 56 members and visitors, who were privileged to hear Dr. Hugh H. Bennett, chief, Soil Conservation Service, USDA, give a very informative and inspiring presentation on the policies and problems of the federal agency of which he is head.

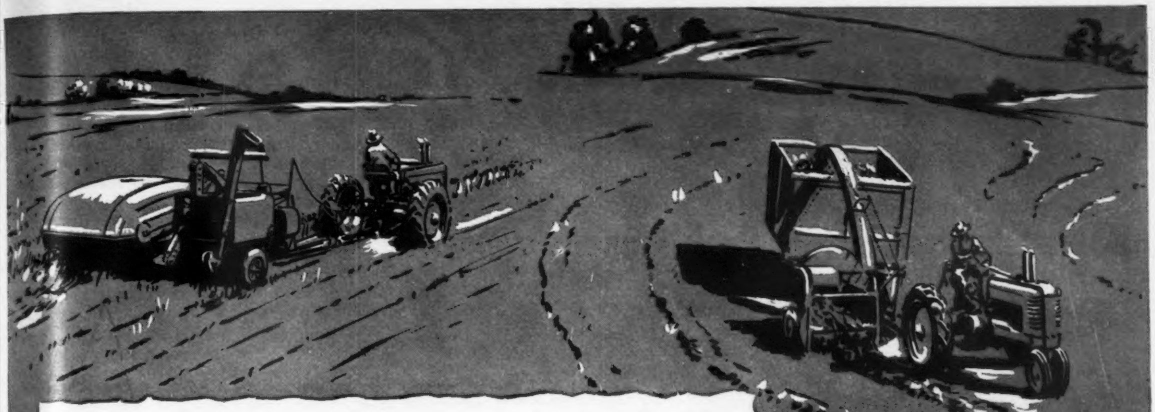
At the close of the meeting, a meeting was held of members of the committee on local arrangements for the 1950 ASAE annual meeting which will be held in Washington, June 19 to 21. The committee reports that plans for the meeting in June are well advanced and adequate preparations are being made to insure that those attending the meeting will find it a most enjoyable and profitable experience.

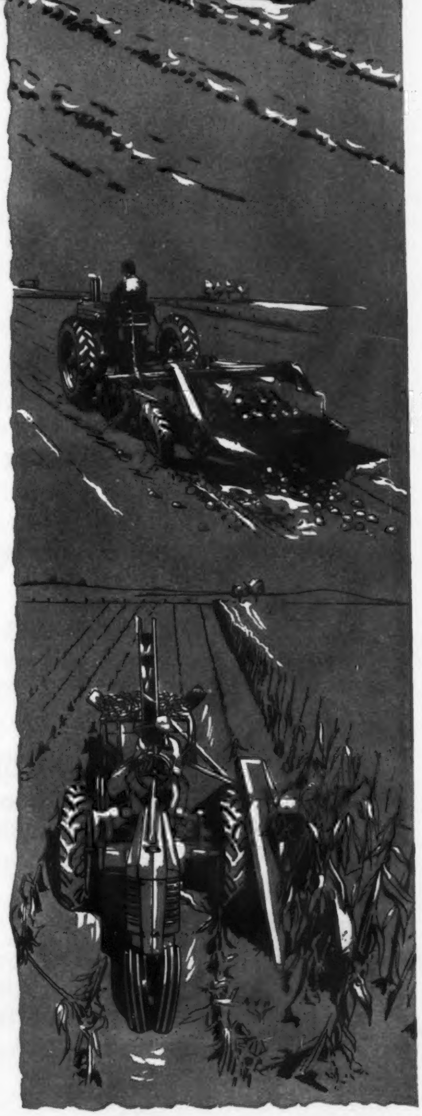
ASAE Hawaii Section Activities

THE second meeting of the Hawaii Section of the American Society of Agricultural Engineers since its formal organization was held February 22nd at the Agricultural Engineering Institute on the University of Hawaii campus.

Arnold B. Skromme, agricultural engineer, Pineapple Research Institute, described and answered questions relative to a 96-in powered disk plow, a 6-ft moldboard plow, and a disk harrow powered by power take-off. The machines were inspected while on a mainland tour. Following this discussion, Mr. Carter, of Locke (Continued on page 142)

The U. S. Department of Agriculture dairy farm is one of the many interesting sights at the Beltsville Research Center that those who attend the 1950 ASAE Annual Meeting at Washington, D. C., June 19 to 21 will want to see





NEWS SECTION

(Continued from page 140)

and Co., showed films describing new devolpments by Harry Ferguson, Ltd., including a disk plow, hay rake, etc.

Rene Guillou, head, department of agricultural engineering, University of Hawaii, gave an informative discussion of the organization of the American Society of Agricultural Engineers. Membership grades, eligibility, and the procedure for making application for membership were among the questions answered.

The executive committee of the Hawaii Section is getting organized to serve the Section to the fullest extent and expand agricultural engineering activities within the territory. A program committee will be appointed composed of men from various organizations serving agriculture, and members of this committee will serve for one year and be responsible for outlining future programs and publicity.

Oregon A-E Department ECPD Accredited

ACCORDING to announcement received recently the agricultural engineering department of Oregon State College has been fully credited by the Committee on Engineering Schools of the Engineer's Council for Professional Development.

Other college agricultural engineering departments that are now fully ECPD accredited are those at the University of California (Davis), Iowa State College, Kansas State College, and University of Nebraska.

Chemurgists to Feature Green Frontiers

"GREEN FRONTIERS" is the theme for the fifteenth annual chemurgic conference sponsored by the National Farm Chemurgic Council, to be held March 29 to 31, in Washington, D. C.

Announced subjects of particular interest to agricultural engineers from the standpoint of engineering applications to farm production for chemurgic use, include "Soil Conservation and Chemurgy," by Kent Leavitt, "Chemurgy on an Illinois Farm," "Our Farm is 100 per cent Chemurgic," "Democracy is Dependent Upon Conservation," and "Reforestation and Land Reclamation By-Products of Chemical Industry."

Other program subjects of wide general interest will include "Nature's World Currencies," "Advances in Crop Use Research, "by Dr. G. E. Hilbert, USDA, and "Chemurgy at the Midwest Research Institute."

The Honorable Charles F. Brannon, Secretary of Agriculture, is scheduled to address the conference on a subject not yet announced.

Personals of A.S.A.E. Members

D. A. Milligan was recently promoted to the position of domestic sales manager by Harry Ferguson, Inc. He joined the company in 1943 as director of research and was later made director of service. During the past year he has supervised implement purchasing, implement quality control and production engineering, and acted as assistant to the director of distribution. Prior to joining the Ferguson organization, Mr. Milligan was for several years employed as equipment sales engineer by the Cleveland Tractor Company, and during World War II he served as a special consultant to the Farm Machinery Division of the War Production Board.

R. E. Morris, who until recently held the position of agricultural engineer with A. M. Todd Co., Kalamazoo, Mich., has organized the Morris Engineering Co., LaPorte, Ind., where he will engage in the sale of a line of irrigation equipment and also a land drainage pump of his own design, and will in addition engage in consulting work.

Ben D. Moses, professor of agricultural engineering, University of California, who for the past 25 years has served as secretary of the California Committee on the Relation of Electricity to Agriculture, was recently honored by the Pacific Coast Electrical Association with a plaque commemorating his service to farm electricification. The California CREA has carried on a consistent and continuous program in research and education in farm electrification, and many departments of the University have cooperated and still are cooperating in the activity.

David C. Sprague, professor of agricultural engineering, Pennsylvania State College, has accepted appointment as agricultural engineering consultant to Libbey-Owens-Ford Glass Co., Toledo, Ohio, during his sabbatical leave of absence. He will be engaged in research on the application of the principle of solar heat and the use of Thermopane insulating glass in windows of farm structures, in collaboration with W. Everett Eakin, director of farm research for the Company. Sprague will help to correlate information for the Company on research projects which have been set up in cooperation with a number of agricultural experiment stations, and his observations will include ventilation and insulation of buildings, as well as window planning to provide desirable environmental conditions for livestock and poultry. Sprague's recent work in collaboration with poultry husbandry department of Pennsylvania State College on the mechanical feeding of poultry and the efficient use of labor has attracted nation-wide attention.

RESEARCH NOTES

A.S.A.E. members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.

USDA Notes on Insect Trap Conference and New Agricultural Information Series

Electric Insect Trap Conference. The Farm Electrification Division, USDA, recently held a meeting to discuss the present status of electrocuting devices for insect control and to consider objectives and plans for 1950. All manufacturers of electric traps, members of the agricultural press, and interested entomologists and agricultural engineers were invited. Guests were welcomed by Assistant Secretary Knox T. Hutchinson. Talks were given on the various methods of controlling insects, including Indiana experiments with electric traps in control of the corn borer, North Carolina observations on electric trapping of the tobacco hornworm, and Iowa experience with electric traps. Electrical hazards in the design and application of electrocuting devices for insects was the subject of another paper. The afternoon session was devoted to an open discussion for consideration of mutual problems.

New Information Series. The USDA Divisions of Agricultural Engineering have recently issued three new numbers (95, 96 and 97) in their Information Series. IS 95 is a bibliography on spraying and dusting equipment compiled from the *Bibliography of Agriculture* of the USDA library for the period February, 1942, through April, 1949. IS 96 is a list of current research projects of state agricultural experiment stations and the USDA on application equipment for crop and animal pesticides, weedicides, hormones and other growth regulators, defoliants, plant nutrients (above ground), and soil fumigants. These two mimeographs were prepared at the request of the Pesticide Application Equipment Committee, a liaison group representing the Agricultural Chemicals Association, the Power Sprayer Division of the Farm Equipment Institute, and the National Sprayer and Duster Association. Copies have been mailed to all agricultural engineering departments and to the directors of the agricultural experiment stations.

The third of the new numbers, IS 97, is the first annual report of research accomplishments in farm machinery and equipment by public research agencies of the state agricultural experiment stations and the USDA. It is in answer to a request of the Agricultural Research Committee of the Farm Equipment Institute that BPISAE agricultural engineers serve as a clearinghouse for information relating to public service in the farm machinery and equipment field. The research accomplishments are listed by states in Part I and by major operations in Part II. Agricultural engineering departments and experiment station directors will receive this report.

This Papec Model L hay chopper, equipped with auxiliary power unit, is used for chopping and distributing a straw or hay mulch on the shoulders of new highway construction. It makes the mulching operation much less expensive than when the spreading is done by hand

Advanced Row Crop Features Make Advanced Practices Easier!

Following a rigid soil-saving program calls for modern, maneuverable equipment. That's why an Oliver Row Crop "77" is the perfect choice for today's diversified operations. Its six forward speeds and husky 6-cylinder engine provide the proper working pace and power for a full range of approved conservation practices—from terrace construction to caring for cultivated crops on the contour.

A Direct Drive Power Take-Off, equipped with an independent clutch, saves field time and increases the efficiency of PTO-driven machines. Grouped, automotive-type controls make the Row Crop "77" as easy to drive as a car . . . a revolutionary, rubber torsion spring seat supplies unequalled comfort. In addition, 31 mounted implements and attachments are available to meet a multitude of needs. The Oliver Corporation, 400 West Madison Street, Chicago 6, Illinois.

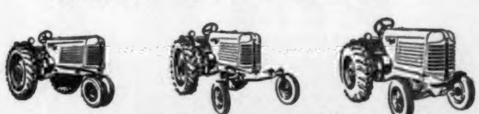
A parallelogram coupling keeps Oliver tractor-mounted tilling, planting and cultivating tools on an even keel. These diagrams show how the gangs always stay level and are permitted to float independently.

Here's an example of Oliver's farm-engineering approach that results in equipment that does a more efficient job. In addition, under the new Oliver standardization program all mounted tools are basically interchangeable among the current Row Crop tractor models, the "66", "77" and "88". When a farmer steps up his power with larger models or acquires additional units he need not invest in new mounted tools to fit them.

OLIVER

THE OLIVER CORPORATION

"FINEST IN FARM MACHINERY"



Oliver "66", "77" and "88" tractors are built in 6 basic types and 8 variations

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Bogner, Neil F.—Engineer, Soil Conservation Service, USDA. (Mail) 1012 Green St., Henry, Ill.

Brenner, Walter—Institute director, Braunschweig-Volkenrode, Germany

Chapson, Harold B.—President, Chapson & Stickler, Ltd., 755 Sheridan St., Honolulu, Hawaii

Child, James L., Jr.—Sales engineer, The Hancock Brick & Tile Co., Box 59, Findlay, Ohio

Claas, August—Director, Messrs. Gebr. Claas, Harsewinkel (Westfalen) Germany

Claycomb, Richard S.—Associate agricultural engineer (BPISAE), USDA. (Mail) Agricultural Engineering Department, N. J. College of Agriculture, New Brunswick, N. J.

Cleveland, Roger M.—Assistant professor of agricultural engineering, University of Arkansas, Fayetteville, Ark.

Corey, G. L.—Assistant irrigationist (research), Idaho Branch Experiment Station, Aberdeen, Ida.

Cowley, Earl W.—Irrigation engineer (research), Soil Conservation Service, USDA. (Mail) Box 786, Grand Junction, Colo.

Cox, James L.—Agricultural engineer, applications & loans div., Rural Electrification Administration, USDA, Washington, D. C.

Elam, Charles W.—Agricultural engineer, A. & L. Div., Rural Electrification Administration, USDA, Washington 25, D. C.

Fergason, R. C.—Chief engineer, Gadsden Works, Allis-Chalmers Mfg. Co., Gadsden, Ala.

George, W. Lee—Sales engineer, Fafnir Bearing Co. (Mail) 316 Campbell St., Geneva, Ill.

Gibbsson, Rolf, Jr.—Salesman, Nerliens Kem-Tekn. A/S Tollbodgt 32, Oslo, Norway

Goins, Truman—Assistant agricultural engineer, Ohio State University, Columbus 10, Ohio

Gunn, Jack T.—Junior specialist in agricultural engineering, University of California, Davis, Calif.

Hartzog, W. L.—Progressive student, International Harvester Co. (Mail) 3315 Norwood Blvd., Birmingham, Ala.

Heising, Robert A.—521 W. Washington, Kirkwood 22, Mo.

Imhof, Alvin G.—Agricultural engineer, Soil Conservation Service, USDA. (Mail) R R 2, Waller, Texas

Jarecki, Eugene A.—Hydrologic engineer, Bureau of Reclamation, Grand Island, Nebr.

Johnson, J. V.—Engineer, water conservation, PFRA, Box 664, Melville, Sask., Canada

Kemp, John G.—Officer in charge of power and tillage studies, Dominion Experimental Station, Swift Current, Sask., Canada

Kistler, James B.—Assistant superintendent of college farms, Pennsylvania State College, State College, Pa.

Lawrence, George E.—Field engineer, Manhattan Rubber Div. of Raybestos-Manhattan, Inc., 1330 East 10th St., Davenport, Iowa

Leatherwood, Frank N.—Agricultural engineer, Soil Conservation Service, USDA. (Mail) Box 248, Burnet, Tex.

Lewis, R. W.—Mgr., general dealer sales, Fairbanks Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

Lovegreen, J. R.—Manager, farm equipment research, Ralston Purina Co., 835 South 8th St., St. Louis, Mo.

Marlow, A. S., Jr.—President, Marlow Pumps, Ridgewood, N. J.

McCoy, E. C.—Inspector and construction engineer, Norfolk & Western Railway. (Mail) 209 Chesterfield Ave., Colonial Heights, Va.

McFee, Roy E.—Designing engineer, Grand Trunk Western Railroad. (Mail) 14925 Rosemont, Detroit 23, Mich.

Mellen, John F.—Field engineer, Tela Railroad Co., La Lima, Honduras

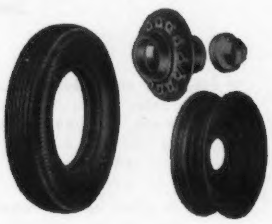
Merkel, Charles M.—Agricultural engineer, Cotton Ginning Laboratory (BPISAE), USDA. (Mail) Box 145, Leland, Miss.

Newell, John A.—Sales representative, Dickerson Machinery Co. (Mail) 3017 E. Jackson Ave., Spokane, Wash.

(Continued on page 148)

Rolls right along with a 2 ton load

...that's why
a NEW IDEA wagon
is a good idea



***WHEELS AND TIRES** are all one size. Pressed steel, demountable disc wheels have drop center rims. Dustproof hub construction and steel hub cap protect axle from dust and grit. Tires are 6.00-16, 4-ply heavy duty auto type.*

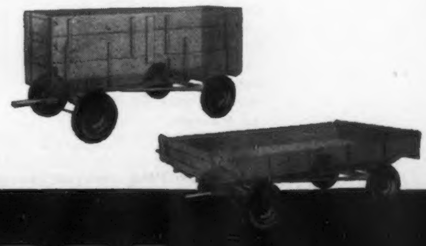
With practically every farm task beginning and ending with a hauling job, NEW IDEA engineers have given the same specialized study to farm transportation as they have to other operations which require more complicated machines. That's why, with the NEW IDEA Farm Wagon, bigger loads can be moved in less time with greater safety, and haulage costs are reduced to a minimum.

This rugged, all-steel, all-purpose wagon meets every farm requirement . . . can be equipped for use with tractor or team. Wheel base and bolster stakes are fully adjustable to fit all types of wood or metal beds, racks and boxes. Brakes and other extra equipment are available for special needs.

Here is a farm wagon which definitely is built to do a better job — one which you can recommend with confidence to anyone who wants greater efficiency in farming operations. See your local NEW IDEA Dealer or write for more information.

***STEERING MECHANISM** has socket for floating tongue, adjustable steering rods, hardened bushings. Lost motion is eliminated. Wagon trails perfectly and has shorter turning radius.*

***FULLY ADJUSTABLE** to fit all types of wood or metal beds, racks or boxes.*



NEW IDEA

DIVISION AVCO MANUFACTURING CORPORATION
COLDWATER, OHIO SANDWICH, ILL.

PROFESSIONAL DIRECTORY

Applicants for Membership

(Continued from page 146)

Sherwood, James N.—Agricultural engineer, Rural Electrification Administration, USDA. (Mail) 2758 N. Washington Blvd., Arlington, Va.

Singhal, A. P.—Lake House, Udaipur, Rajasthan, India.

Speiser, Heinz K.—Professor, agricultural college, University of Kiel, Kronshagener Weg 7, Kiel, Germany

Tenorio, Humberto—Ave. 2a No. 4-24 Cali, Colombia, S. A.

Tice, Bruce K.—Assistant chief engineer, New Idea Div., Avco Mfg. Co., Coldwater, Ohio

TRANSFER OF MEMBERSHIP GRADE

Male, Charles T., Jr.—Associate professor of civil engineering, Union College, Schenectady 8, N. Y. (Junior Member to Member)

Miller, W. M.—Instructor and research assistant in agricultural engineering, University of Wyoming, Laramie, Wyo. (Junior Member to Member)

Taylor, John G.—Associate agricultural engineer, USDA. (Mail) Agricultural Engineering Department, Purdue University, Lafayette, Ind. (Junior Member to Member)

Thompson, H. M.—Sales engineer, Bolens Products Div., Food Machinery & Chemical Corp. (Mail) R R 1, Jamestown, N. Y. (Junior Member to Member)

EDITORIAL *(Continued from page 109)*

wads. It has listened in on ASAE meetings with an alert, albeit constructively skeptical ear, for so long that it must have noted the trend of the farm equipment industry toward increasing respect for the applied "book larnin' " of agricultural engineering.

If in recent years FIN has editorially espoused the cause of the Association for the Use and Perpetuation of the Farm Horse at any Cost, such items have escaped our notice. We are conscious of the fact that FIN's three top editors have elected to fraternize with teachers of agricultural engineering, graduate agricultural engineers, and others who recognize agricultural engineering as more than a pseudo-scientific racket, by maintaining membership in the ASAE.

In fact FIN's editorial pitchfork is not only well mechanized, but at least one of its diligent attendants at its controls is an agricultural engineering graduate.

Thanks FIN for "yust donatin' your time" and space, in order that your important group of readers may be well informed on the value to them of agricultural engineering education for the future designers of the products they sell; for some of their future employees, partners, and customers, and for men in public service research, extension, and teaching whose work helps increase the demand for equipment for more effective farming.

Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN (1949): MAY—O-668. AUGUST—O-34-675, 34-678, 59-680. SEPTEMBER—O-84-682. NOVEMBER—O-85-689, 127-690. DECEMBER—O-165-691. (1950): JANUARY-O-189-692, 195-694, 197-695, 197-696, 201-697. FEBRUARY—O-232-698.

POSITIONS WANTED (1949): APRIL—W-239, 248. MAY—W-258, 271. JULY—W-288, 292, 299. AUGUST—W-24-304. SEPTEMBER W-67-312. OCTOBER—W-111-316. NOVEMBER—W-119-319. DECEMBER—W-152-322, 145-323,146-324, 151-325, 137-327, 157-328, 97-239, 161-330. (1950): JANUARY—W-164-331, 138-332, 174-333, 175-334, 179-335, 171-336, 177-337, 190-338, 202-339. FEBRUARY—W-203-340, 198-341, 199-342, 214-343, 208-344, 218-345, 222-346, 209-347, 217-348, 213-349.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER for work on irrigation practices and land development in north west-central area, in federal agency. BS degree in agricultural or civil engineering. Field and office experience on earthwork and engineering structures desirable. Must be healthy, cooperative, and industrious. Usual opportunities in federal civil service. Housing suitable for married men with children is difficult to find near the work area. For this reason a single man or married man without children is preferred for this position. Age 25-50. GS-5 rating, salary $3100. O-225-699

PRODUCT DRAFTSMAN for drafting on haying and harvesting tools and related equipment with farm equipment manufacturer in the Midwest. Must be good on layout work. Salary $230-330 mo. O-262-700

JUNIOR PRODUCT ENGINEER for development work on haying, harvesting, and related equipment with farm equipment manufacturer in the Midwest. BS deg in engineering, or equivalent and 3 yr actual design experience. Salary $295-395 mo, depending on qualifications. O-262-701

AGRICULTURAL ENGINEER to become staff member in the agricultural engineering division of a land grant university in the north central area. Work will be teaching courses in physics and engineering, and research in rural electrification. Prefer man with MS deg in agricultural engineering, or equivalent, but outstanding candidates with BS deg will be considered. Any experience indicating ability as a research worker and teacher would be desirable. Usual personal qualifications for college position. Permanent position, 12-mo basis. Opening effective July 1. Normal opportunity for advancement. Age 25-30. Salary about $4000. O-244-702

AGRICULTURAL ENGINEER (appraiser), to analyze drainage facilities, levee and flood conditions in three-state area of central Mississippi Valley. BS deg in agricultural or civil engineering. At least 3 yr experience in drainage and flood control engineering required. Practical knowledge of farming desirable. Good health and ability to inspire confidence and command respect. Opportunity for advancement good. Age 30-40. Salary, up to $4500 to start, depending on qualifications, plus actual travel and subsistence expense. Give personal qualifications and willingness to travel. Address P O Box 491, St. Louis, Mo. O-253-703

INSTRUCTOR or assistant instructor to teach farm machinery, basic mathematics, and physics in an eastern state agricultural and technical institute. BS deg in agricultural engineering, or equivalent. MS deg desirable but not essential. Farm background, some experience in farm equipment industry, and skill in repair and adjustment of farm machines necessary. Must be able to work with students, dealers, and distributors. Initial assignment for one year beginning on or about August 1, with possibility of permanent assignment under state civil service. Work on 12-mo basis with 28-day vacation. Age 26-35. Salary $3000-4000. O-267-704

AGRICULTURAL ENGINEER (assistant professor) for teaching and research in various branches of the field, in a northeastern university. BS and MS deg in agricultural engineering, or equivalent. Good character and personality. Will consider all applicants, regardless of experience. Normal opportunity for advancement in academic rank and salary. Age, under 40. Salary $3700-4300 range, 12-mo basis, one month vacation. O-270-705

NEW POSITIONS WANTED

TEACHING, extension, or research in power and machinery, with college or private industry anywhere in U.S.A., possibly elsewhere. BS deg in agricultural engineering 1945, University of Saskatchewan. MS deg in agricultural engineering, 1949, Iowa State College. Experience in wheat farming with large machinery. Instructor at University of Saskatchewan, 7 mo. Drafting for town planning commission, 3 mo. Conducting extension field days, 1 mo. War service in Canadian Army 4 mo. (released to instruct in University). Single. Age 28. No disability. Available now. Salary open. W-219-350 *(Continued on page 152)*

PERSONNEL SERVICE BULLETIN

(Continued from page 150)

SERVICE in soil and water field, with private industry, preferably in Midwest or West. BS deg in agricultural engineering, January 1950, Louisiana State University. Experience in dam and levee building, 6 mo; terrace building 3 mo; hydrologic survey of watersheds, 3 mo. Naval enlisted service 6 yr, with advancement to Chief Petty Officer. Single. Age 27. No disability. Available now. Salary $3600. W-227-351

EXTENSION, teaching, or research in rural electrification, in public service or private industry, anywhere in U.S.A., U.S. possessions, or South America. BS deg in agriculture, major in agricultural engineering, Michigan State College, 1949. Michigan farm background. Radio technician 8 yr. Part-time construction worker, 3 yr while in college. Electrification advisor for rural electric cooperative since June 15, 1949. War noncommissioned service in Army Air Force. Married. Age 30. No disability. Available on reasonable notice. Salary $3800. W-247-252

SALES OR SERVICE in power and machinery on soil and water field in public service or private industry. Any location. Willing to travel abroad. BS deg in agricultural engineering, 1949, University of Saskatchewan. Background on mechanized grain farm. General construction work, 6 mo. Assistant district engineer 1 yr, with government agency on small water projects, drainage, etc. Single. Age 23. No disability. Available in September. Salary $3000. W-228-353

DESIGN, development, or research in power and machinery or soil and water field with a manufacturer in the Midwest. BS deg in agricultural engineering expected in March, Ohio State University. Specialized in mechanical and electrical engineering phases. Summer experience in 1949, 3 mo in design work with experimental department of a farm equipment manufacturer. Part time work while in school making soil survey maps. War enlisted service 2½ yr in Corps of Engineers. Married. Age 25. No disability. Available April 15. Salary $3000. W-231-354

RESEARCH or teaching in the power and machinery field, in a college, anywhere in the U.S.A. BS deg in agriculture June 1948, BS deg in in mechanical engineering expected in August 1950, University of Wisconsin. Instructor in aircraft engines 2 yr. Instructor in farm power and machinery, farm shop, and rural electrification (half time) 2 yr. Research assistant on field hay drying one summer. War noncommissioned service in Army Air Force 4½ yr. Married. Age 32. No disability. Available September 1. Salary $3600. W-256-355

DEVELOPMENT, research, sales, or service in the power and machinery or soil and water field, with experiment station or private industry, anywhere in U.S.A. BS deg in agriculture, June 1948, South Dakota State College. Farm background. Part time work in agricultural engineering department while in school, including running soil samples, blueprinting, and assistant laboratory instructor in farm machinery. Farming since graduation. War commissioned service in Naval Air Corps as pilot 2¾ years. Married. Age 26. No disability. Available now. Salary open. W-240-356

EXTENSION, teaching, and research in farm structures or soil and water field, with college or experiment station in Southwest or West. Particularly interested in position which would provide opportunity for advanced study. BS deg in agricultural engineering, 1947, Oklahoma A & M College. MS deg in agricultural engineering expected in June, Purdue University. Farm background with work in irrigation. Teaching in soil and water field, 2½ yr. Research in farm structures, 3 yr. War enlisted service in Navy, 1 yr. Married. Age 23. No disability. Available July 1. Salary open W-248-357

SERVICE work with power and machinery on large-scale grain farm for several months practical experience before returning to China. MS deg in agricultural engineering Kansas State College, January 1950. Worked in machine shop in China, 1940-45. Single. Age 31. No disability. Available now. Salary open. W-252-358

TEACHING and research in power and machinery, rural electric, or mechanical or electrical engineering field, in college in U.S.A. BS deg in electrical engineering, 1944. MS deg in agricultural engineering, 1949, University of Minnesota. Electronic design engineer, 1944. Instructor in electrical engineering, 1944-1949. Research associate in agricultural engineering, summer session 1948. Single. Age 27. No disability. Available now. Salary open. W-257-359

DESIGN, development, or research in power and machinery or soil and water field with federal agency or manufacturer, anywhere in the U.S.A. or Canada. BS deg in agricultural engineering expected in May, University of British Columbia. Farm background. Experience in land classification, irrigation, drainage, and soils, in summer employment with British Columbia department of lands and forests, 5 mo. Summer employment in machine shop of industrial organization, 5 mo. War service 2 plus years in Royal Canadian Naval Voluntary Reserve. Single. Age 25. No disability. Available May 20. Salary open. W-246-360

SALES, service, or writing, in power and machinery or rural electric field, in public service or private industry in U.S.A. Interested in opportunity for further training. BS deg in agricultural engineering, expected in June, University of Connecticut. General farm background. One summer as rural electrification engineering aid with public utility. One summer in repair and maintenance of industrial equipment. War enlisted service in Navy 2 yr plus. Single. Age 24. No disability. Available June 12. Salary open. W-268-361

DEVELOPMENT, extension, or service work in power and machinery or rural electric field with college, experiment station, manufacturer or distributor. Any location. BS deg in agricultural engineering expected in May, University of British Columbia. Dairy farm background. Radar mechanic 4½ yr, R.C.A.F. Mechanic 5 mo, Pacific Tractor and Equipment Co. Part time salesman for same company while in school. Married. Age 27. No disability. Available May 15. Salary open. W-258-362